JOINT CANNERY OUTFALL
MODEL PREDICTION VERIFICATION STUDY

Report No. 1

for

StarKist Samoa, Inc.

and

VCS Samoa Packing Company

to comply with NPDES Permits

AS0000019

AS0000027

July 1995

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EXECUTIVE SUMMARY

This is the first Model Verification Study report required under the NPDES permits for StarKist Samoa and VCS Samoa Packing for discharge through the joint cannery outfall (JCO) in Pago Pago Harbor, American Samoa. The objective of the study is the verification of models used to determine the permitted zone of mixing (ZOM) for the JCO. The study is divided into three separate tasks: [1] verification of initial and subsequent dilution models, [2] verification of the wastefield transport model, and [3] examination of the effects of BOD_5 in the effluent on the dissolved oxygen in the receiving waters of Pago Pago Harbor.

The verification of the plume dilution models involved running the models under the environmental conditions observed during two dye studies and comparing the results to the dilutions calculated from measured dye concentrations. The initial dilution model, UDKHDEN, was found to have predicted the initial dilution of the plume quite well. Under certain conditions, weak density gradient and bathymetric induced upwelling, care must be taken in the interpretation of the model output. The subsequent dilution model was found to be somewhat conservative (under predicts actual dilution), as expected.

Verification of the previous model predictions of long-term ambient nutrient levels for the relocated cannery discharge through the JCO was accomplished by comparison of model predicted concentrations with concentrations measured during the water quality monitoring program. The model used, PT121, was found to be somewhat conservative (over predicted concentrations). The degree of conservatism was as expected. It was not considered necessary to adjust model parameters such as diffusivity at this time.

The evaluation of BOD impacts was done with a screening level approach to determine the approximate magnitude of impacts. This approach includes the assessment of extreme worst case scenarios to estimate an upper bound to the potential impacts. The evaluation, and model simulations used, considered only the possible impacts from the JCO. The model used for the evaluation was the same model, PT121, used for the evaluation of nutrient discharges. The results of the evaluation indicate that BOD loads from the JCO, at the current discharge location, do not impair water quality in the Harbor.

The model verification elements described above, and the water quality data used in the study, were used to evaluate the definition of the ZOM. Compliance with water quality standards throughout the harbor appears to have been generally attained. The models appear to have done a good job in previous predictions and the model simulations used to develop the diffuser design, the outfall location, and the ZOM have been verified based on available data. Recommendations regarding the model verification study are presented in Section 5 of the report.

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Section 1

INTRODUCTION

This report presents the results of the initial model prediction verification study for the Joint Cannery Outfall (JCO) in Pago Pago Harbor, American Samoa. The purpose of the study, background, and general approach are presented first. The sections that follow document the model prediction verification study including descriptions of the data and methods used to evaluate previous model predictions and the results of the analyses. The study was done in three parts: initial dilution, nutrient dispersion, and BOD/DO impacts. Subsequent studies required under the NPDES permit will not include the initial dilution element, as discussed below. The report is concluded by a discussion of the results including conclusions and recommendations for incorporation into subsequent studies.

PURPOSE

This study addresses the verification of models used to determine the permitted zone of mixing (ZOM) for the JCO. The purposes of this study are to: [1] verify the previous analyses of the fate and transport of cannery effluent using field data collected after operation of the JCO was initiated, and [2] evaluate effects of the discharge on dissolved oxygen (DO) concentrations throughout Pago Pago harbor.

BACKGROUND

The JCO is an outfall operated by StarKist Samoa, Inc. (SKS) and VCS Samoa Packing Company (VCS). The outfall discharges treated wastewater from the canneries into outer Pago Pago Harbor and replaces individual outfalls that discharged effluent into the inner harbor near the canneries. The canneries moved the discharge point from the inner harbor to the outer harbor, discharging through the JCO, in February of 1992 (with approval from EPA). In addition, prior to initiating discharge through the new outfall, the canneries implemented high strength waste segregation in August 1991. The high strength waste is disposed of in a permitted ocean disposal site and does not influence the harbor.

The effects of high strength waste segregation and outfall discharge relocation on the water quality of the harbor were modeled by CH2M HILL (1991a). The size and location of the ZOM was based on environmental and engineering studies which included model predictions of the initial and subsequent dilution and the farfield transport processes (CH2M HILL, 1991a; 1991b). NPDES permits were issued (effective date of permit [EDP] of 27 October 1992) based on the approved zone of mixing.

The NPDES permits require implementation of a receiving water quality monitoring program to determine compliance with water quality standards. The monitoring program is being conducted by the American Samoa Government (ASG) through the American Samoa Environmental Protection Agency (ASEPA). The monitoring program includes monthly collection and analysis of water samples from 17 specified stations throughout the harbor. The objective of the monitoring program is to document water quality near the outfall discharge within the ZOM, at the ZOM boundaries, and at locations throughout the harbor. The permits require monitoring reports documenting the water quality data be submitted to US Environmental Protection Agency (USEPA) on a quarterly basis.

Two dye studies were also required as conditions of the permits to observe the fate and transport of the effluent plume. The first (non-tradewind season) of these dye studies was conducted on February 17, 1993 (CH2M HILL, 1993). The second (tradewind season) was conducted on October 12, 1993 (CH2M HILL, 1994).

The data collected from the water quality monitoring program and from the dye studies allow direct observation of the fate and transport of the discharged effluent. The NPDES permit requirements dictate that these data be used to verify the model predictions used in the earlier engineering studies for determining the ZOM and to evaluate the effects of BOD in the effluent on DO in the receiving water. This requirement is described in Part J of NPDES permit Numbers AS0000027 and AS0000019 as follows:

> *"Within three months after both dye studies have been completed, the permittee, cooperatively with {Star-Kist Samoa, Inc.; Samoa Packing Co.}, shall submit a study plan to USEPA and ASEPA that will discuss how the permittees will utilize the results from the monitoring data and from the dye studies to verify the models used in the determination of the mixing zones (the 30-second dilution zone, the ZID, and the ZOM). Also, the plan shall discuss how the permittee will examine the effects of BOD_5 in the effluent on Dissolved Oxygen (DO) in the receiving water, utilizing an appropriate model and one year's worth of ambient data. Upon approval of the study plan by USEPA and ASEPA, the permittee shall initiate the studies indicated and submit reports on a yearly basis. Reports shall summarize renewed predictions of dilution rates and the size, location, and movement of the plume based on the calibrated models".*

The study plan was submitted to USEPA and ASEPA on August 27, 1993 and approved by USEPA on 1 November 1993. Dr. Walter FricK of USEPA reviewed the study plan and had two comments which were included in the letter of 1 November 1993. The study plan, USEPA's approval letter, and our response to Dr. Frick's comments are included in an addendum to this report. ASEPA had no comments on the study plan (telephone conversation with Sheila Wiegman of

ASEPA, November 1993). This study is the first of the reports to be submitted to the USEPA and ASEPA in compliance with the permit conditions, and covers the first year of operation of the JCO and the two dye studies.

GENERAL APPROACH

The study is divided into three separate tasks:

1) **Model Verification - Initial and Subsequent Dilution.** The modeling procedures used to establish the mixing zone are evaluated based on data collected during the dye studies.

2) **Model Verification - Wastefield Transport.** The modeling procedures used to establish the mixing zone are evaluated based on data collected during the water quality monitoring program.

3) **BOD Impacts.** The effects of BOD_5 in the effluent on the DO in the receiving waters of Pago Pago Harbor are addressed based on the existing information and the results of the model verification elements listed above.

The basic approach used in the previous engineering study (CH2M HILL, 1991a) to determine the required mixing zone dimensions were: estimate the large-scale, long-term average ambient receiving water concentrations using a wastefield transport model, evaluate initial and subsequent (or secondary) dilution for a range of conditions, and, based on model predictions, determine the appropriate location for the discharge and the required size of the ZOM to comply with American Samoa Water Quality Standards (ASWQS).

This study evaluates this approach by re-running the models for the conditions measured during the dye studies and water quality monitoring, as appropriate, and comparing the model results with the observed field data. The ZOM location and dimensions were re-evaluated as reported in the results section (Section 5) of this report. Each of the major tasks of the study are described below.

Initial and Subsequent Dilution Models

The initial and subsequent dilution modeling procedures used to establish the mixing zone boundaries are evaluated based on the dye study results. Model input includes measured currents, temperature and salinity profiles, and effluent flows measured during each dye study. The model results are compared to the dilutions observed during the dye studies and to previous predictions. The formulation of the effluent limits for ammonia were based on predicted diffuser performance in terms of initial dilution rate and magnitude. The predictions used for this purpose are specifically evaluated.

Wastefield Transport Model

Observed long-term average receiving water concentrations, on a harbor wide scale, for total nitrogen (TN) and total phosphorus (TP) are based on concentrations observed at each of the water quality monitoring sampling stations. Average loadings of TN and TP to the harbor from the discharge are calculated for the same period of time. The wastefield transport model was run using these average loadings and evaluated by comparing the model results to the observed water quality data.

BOD Impacts

BOD impacts on receiving water DO were evaluated using the same wastefield transport model employed for nutrients, modified to simulate simple BOD/DO kinetics. The potential impacts of cannery effluent on DO levels throughout the harbor were addressed using the verified wastefield transport model

Section 2

INITIAL AND SUBSEQUENT DILUTION

The general approach to the verification of the plume dilution models is to run the models under the environmental conditions observed in the field during the two dye studies and then compare the results to the dilutions calculated from measured dye concentrations. The initial dilution model used is UDKHDEN and the subsequent dilution model is CDIFF. These were the models used in the outfall design and definition of the ZOM. A brief background is first provided below, with references provided for more complete descriptions, and then each of the models is considered. An evaluation of the results of the model verification applied to the ZOM definition is provided in Section 5 below.

BACKGROUND

Preliminary diffuser configuration and performance for a range of potential conditions and outfall locations were investigated during the Feasibility Study (CH2M HILL, 1991a). The results of this study indicated a general location for the diffuser and provided preliminary diffuser design parameters. The final diffuser configuration was developed during final outfall design based on desired performance and selected design criteria (CH2M HILL, 1991b). The Feasibility Study employed EPA plume models UMERGE and UDKHDEN (Muellenhoff et al., 1985). The UDKHDEN model was selected for final design since it was considered more sensitive to changes in receiving water and effluent characteristics.

The jet momentum and buoyancy induced initial dilution of the plume is rapid and occurs within a limited area. The effluent and constituent concentrations depend on the initial dilution and the concentrations of the receiving water. Since the discharge is in a semi-confined area the ambient receiving water concentrations are affected by the long term loading from the discharge itself. The ambient concentrations of the receiving water were predicted using the wastefield transport model discussed in Section 3 below.

To provide a conservative estimate of required mixing zone size, a subsequent dilution model was used and results superimposed on the ambient concentrations predicted by the wastefield transport model. Subsequent dilution describes the less intense dilution of the plume, driven by relatively high concentration gradients, following the initial dilution process. Subsequent dilution was estimated using the EPA farfield plume dilution model CDIFF (Yearsley, 1987).

INITIAL DILUTION

Initial dilution depends on the diffuser configuration, effluent characteristics, and environmental conditions in the receiving water. The diffuser characteristics are as follows:

- Four (4) active ports (note: there are six ports in the diffuser but two are blocked by removable flanges)
- Port diameter is 5.065 inches (0.12865 m)
- Port spacing is 50 feet (15.24 m)
- Ports are oriented 15 degrees upward from the horizontal and 90 degrees to the diffuser barrel centerline and alternate sides along the springline of the pipe

The important effluent characteristics are effluent density and flow rate. Effluent flow rates varied during the dye studies. Table 2-1 gives the average and range of variation of flow rates for the two dye study periods. Flow rates through the outfall are not measured directly. Flow from the canneries wastewater treatment plants is measured as conveyed into surge tanks from which the effluent is pumped to the outfall. Therefore flows through the outfall during the dye studies were calculated from the initial dye concentrations. The average flow for the first dye study (non-tradewind conditions) was 2.503 mgd (0.1097 m^3/sec) and for the second dye study (tradewind conditions) was 3.063 mgd (0.1342 m^3/sec).

Effluent density is a function of effluent temperature (at the diffuser port) and effluent salinity. Both of these parameters vary and temperature at the diffuser port is not easily measured. However, previous sensitivity studies (CH2M HILL, 1991b) indicate that the model predicted dilution is not very sensitive to effluent temperature (a change of 5 °F results in a change in dilution of about 2-percent). Given the expected range of effluent temperature (85 to 90 °F), an assumed value of 85 °F at the diffuser port is considered a reasonable value to use.

Effluent salinity varies because SKS uses sea water for thaw water and cooling water. Approximately 0.6 mgd of sea water is used by SKS for thaw water. During the second dye study the effluent salinity of the combined discharges was determined and is shown in Table 2-2. The average quantity of sea water in the combined discharge was 1.13 mgd, representing an average fraction of 37-percent of the total effluent flow (Table 2-2). The sea water portion of the flow ranged from 0.69 to 1.64 mgd, which represented 28-percent and 36-percent of the flow at the respective measurement times. The fraction of sea water ranged from 31-percent to 59-percent. Examination of these data in more detail (Figure 2-1) indicates that the percentage of sea water is, typically, a relatively constant fraction of about 35- to 40-percent of the total effluent flow.

Table 2-1. Effluent Flow Rates During Dye Studies			
Non-Tradewind Study (17 Feb 1993)		Tradewind Study (12 Oct 1993)	
Time	Flow (gpm)	Time	Flow (gpm)
0625	3040	0700	2000
0710	2630	0800	1980
0810	1580	0830	1980
0900	1320	0900	2040
0935	1220	0920	1680
1005	1390	1000	1400
1040	1760	1030	3330
1115	2260	1100	1940
1150	1840	1120	1780
1350	1430	1150	1700
1425	1220	1200	1660
1450	1320	1300	1620
1530	1580	1310	1610
Average	1738	1335	1910
		1400	2840
		1430	3120
		1445	3040
		1500	3050
		1530	2730
		1600	1810
		1630	1860
		1715	1730
		Average	2127

Table 2-2. Effluent Density During Second Dye Study (12 Oct 93)							
Time	Sample Temp (°C)	Sample Cond (mmho/cm^2)	Sample Salinity (o/oo)	Effluent Salinity (o/oo)	Effluent Flow Rate (gpm)	Sea Water Fraction	
						mgd	%
0844	25.7	12.23	6.89	13.77	2010	1.12	40
0920	25.8	18.64	10.85	21.69	1680	1.48	63
0950	25.7	11.98	6.73	13.47	1470	0.80	39
1030	25.4	10.93	6.14	12.28	3300	1.64	36
1100	25.7	10.03	5.56	11.12	1940	0.88	32
1120	25.7	9.75	5.39	10.79	1780	0.78	31
1140	26.0	9.94	5.47	10.94	1740	0.77	32
1215	25.8	9.98	5.52	11.04	1650	0.74	32
1240	25.9	17.23	9.94	19.87	1630	1.31	57
1305	25.9	17.58	10.16	20.31	1610	1.33	59
1335	26.4	11.66	6.44	12.89	1910	1.00	37
1405	26.1	11.35	6.30	12.60	2840	1.45	36
1430	26.1	11.32	6.28	12.56	3120	1.59	36
1445	26.1	11.26	6.24	12.49	3040	1.54	36
1530	26.3	10.83	5.96	11.93	2730	1.32	35
1600	26.1	15.17	8.62	17.24	1810	1.27	50
1630	26.3	9.6	5.24	10.47	1860	0.79	30
1715	26.4	9.03	4.89	9.79	1730	0.69	28
Ave	-	-	-	-	-	1.13	37
Note: All effluent samples tested at 2:1 dilution; effluent salinity is two times the sample salinity							

The important environmental properties of the receiving water, for controlling initial dilution, are depth, density, and currents. The diffuser is located on the bottom in about 171 to 176

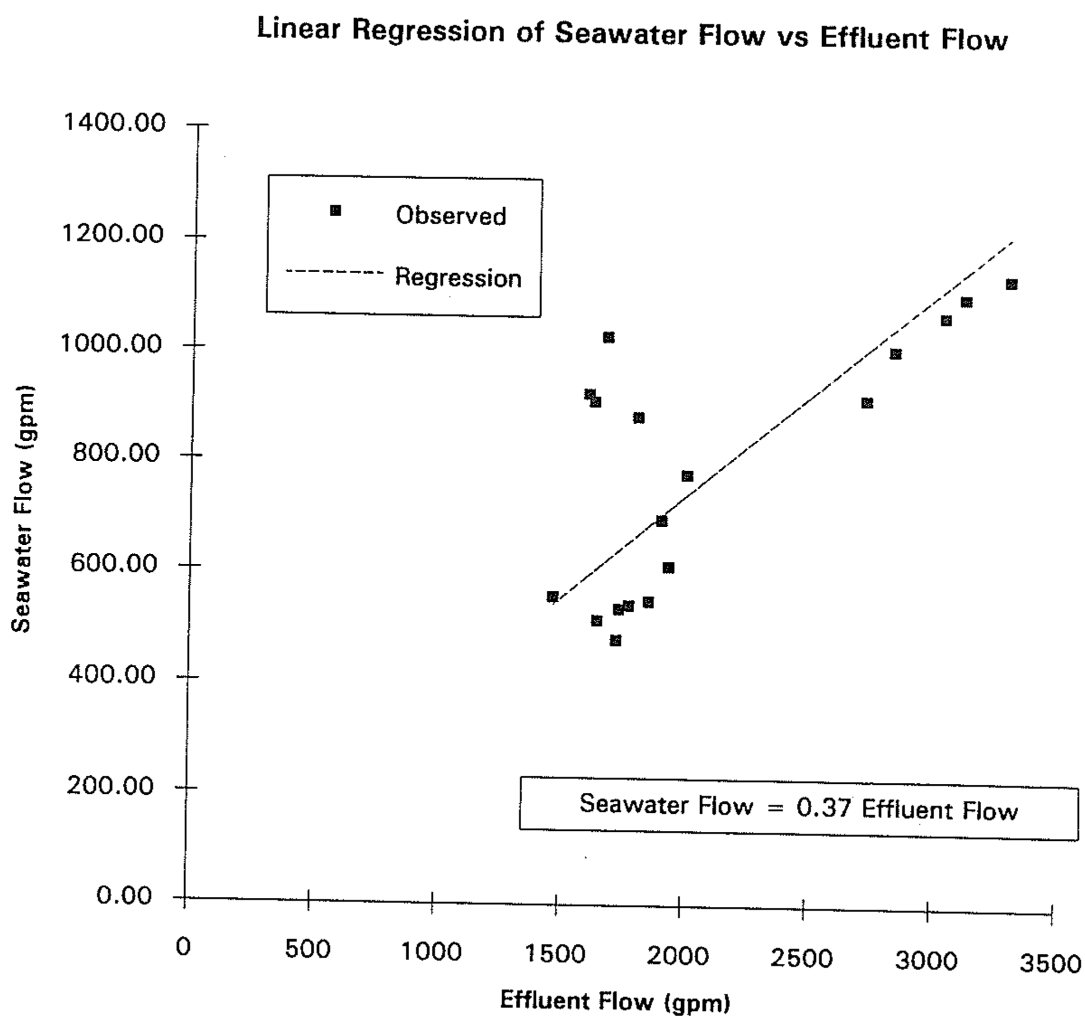

Figure 2-1. Seawater Faction in Effluent

feet of water relative to mean lower low water (MLLW). The tidal range is only about 2.5 feet. Changes in depth will have little or no influence on dilution and a nominal depth of 176 feet is used for all calculations in this study.

Background conductivity-temperature-depth (CTD) profiles were done during each of the dye studies (CH2M HILL, 1993; CH2M HILL, 1994). These data provide vertical density profiles through the water column. Figures 2-2a and 2-2b show the density profiles for the first and second dye study respectively. The figures show the data as collected in the filed and the profiles assumed for the model runs. The filed data is characterized as follows:

- The data for the first dye study displays high variability shallower than 100 feet of water depth. It is suspected that this is due to influence of the effluent plume, observed to be trapped at about this depth, or a problem with the deployment of the instrument. However, the conductivity and temperature measurements below the trapping depth are the important data for the model and these data do not show the same variability. Therefore, the problem of variability in the upper layer is not considered serious. The upper level density, shown in Figure 2-2, was inferred from the available data.

- The second dye study background profile was out of the plume influence. In addition, a pump had been installed on the CTD meter which may help provide better data.

The density was higher and the density gradient below 100 feet was stronger for the non-tradewind (first) study conditions. During the tradewind conditions (second study) there was a very weak gradient except for the surface layer which was a layer of cooler but lower salinity water.

Current speed and direction were measured at two depths (near bottom and mid-depth) during both dye studies. Current profiles were inferred from these measurements. Current directions varied with depth and with time during both dye studies. The current conditions are summarized in Table 2-3. However, the effect of current direction on dilution is relatively small over the range of directions observed. Based on an examination of the data, a current direction 45° to the axis of the diffuser barrel is considered a good overall representation of the prevailing conditions.

The results of the UDKHDEN model simulations are shown in Table 2-4. The model was used for five conditions for each dye study: average, minimum, and maximum effluent flows for each of the dye study periods and a runs for lower effluent temperature and lower effluent density to investigate sensitivity to this parameter as discussed above. The lower effluent temperature runs were done for 80 °F and the lower effluent density runs were done assuming that the effluent included 0.6 mgd of sea water. The model simulation results for the non-tradewind period (Dye Study No. 1, February 1993) quite are consistent with the observed values. The model simulation results for the tradewind period (Dye Study No. 2,

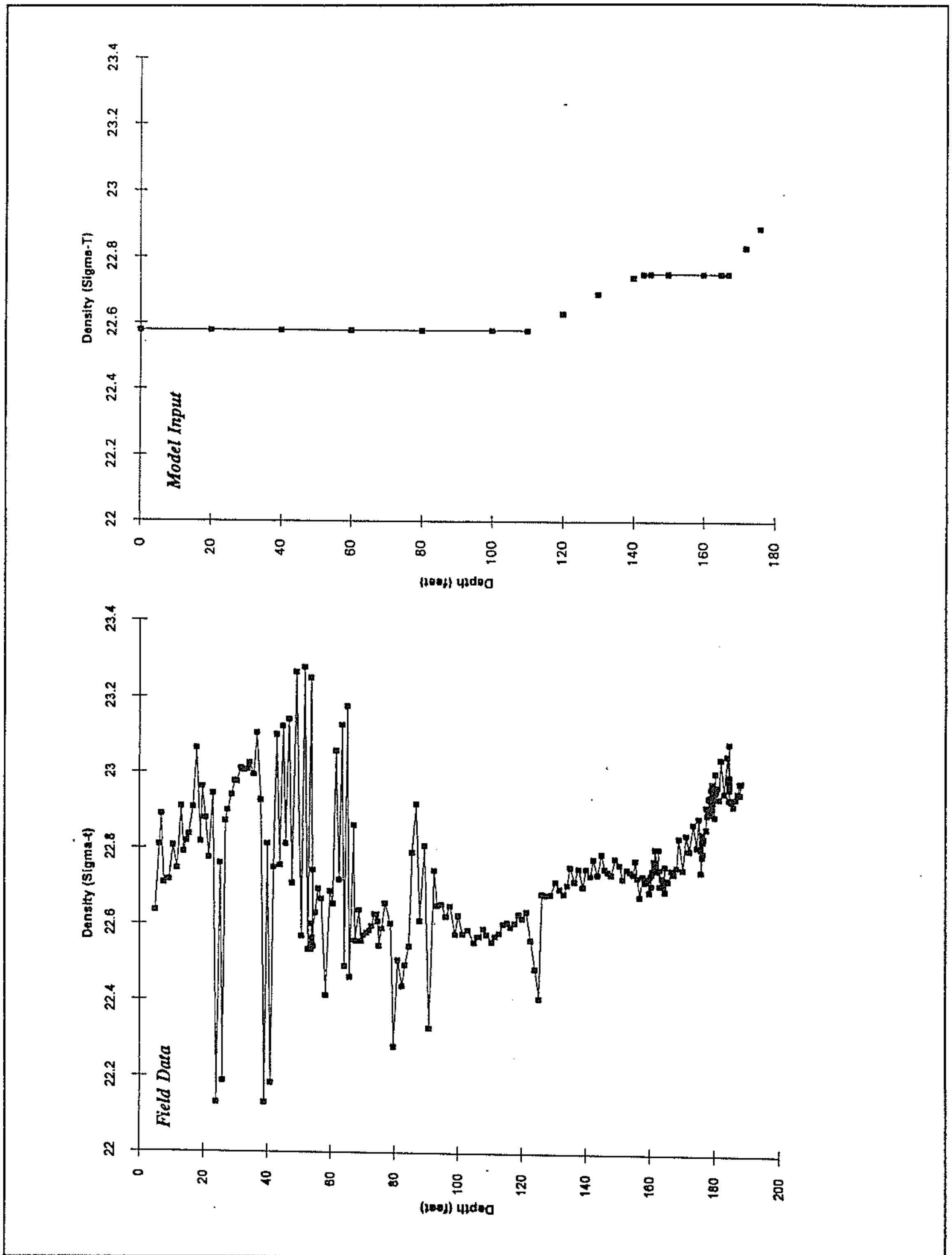

Figure 2-2a. Density Profile During First Dye Study

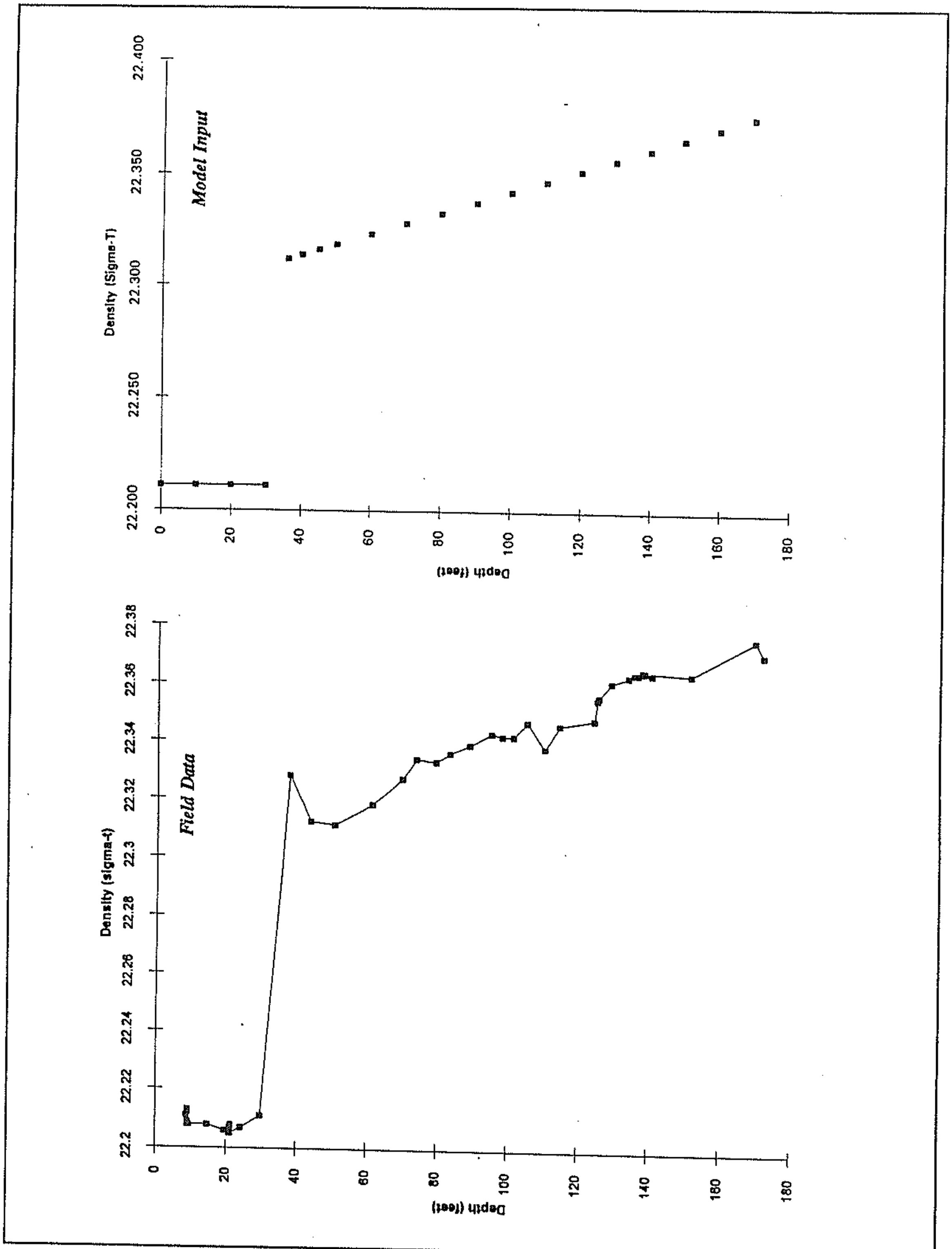

Figure 2-2b. Density Profile During Second Dye Study

Table 2-3. Current Observations			
Time	Meter Depth (ft)	Average Speed (cm/sec)	Predominant Direction (°magnetic)
DYE STUDY No. 1 - NONTRADEWIND CONDITIONS February 17, 1993			
08:00 - 10:30	100	15 - 20	145 - 155
10:30 - 17:00	100	15 - 20	255 - 285
08:00 - 08:30	170	≈2.5	30 -60
08:30 - 11:00	170	2 - 4	300 -330
≈11:00	170	1 - 2	≈270
11:30 - 14:00	170	1 - 2	60 - 90
14:30 - 17:00	170	2 -5	120 - 150
DYE STUDY No. 2 - TRADEWIND CONDITIONS October 12, 1993			
08:00 - 11:00	100	18 - 24	260 - 290
11:00 - 14:00	100	18 - 24	215 - 240
14:00 - 17:00	100	18 - 24	260 - 280
08:00 - 15:00	170	1 - 3	150 - 210
15:00 - 17:00	170	1 - 2	80 - 150

October 1993) appear to be consistent for predicted dilution but are not consistent with observed plume trapping levels.

Detailed UDKHDEN model input and output is provided in Appendix I. The results, and implications for model verification and ZOM definition, are discussed in more detail in Section 5 below. General comparisons of the initial dilution model predications and observations are as follows:

- **For the nontradewind dye study**: the model indicates that an average dilution of between 400:1 and 500:1 is expected (Table 2-3). These dilutions

Table 2-4. Results of UDKHDEN Predictions					
CASE	Flow (mgd) [m^3/sec]	Effluent Density (g/cm^3)	Dilution	Trapping Depth (m)	Plume Width (m)
DYE STUDY No. 1					
Mean Flow	2.503 [0.0197]	1.00467	485	41.2	13.9
Max Flow	4.377 [0.1918]	1.00467	393	40.3	16.0
Min Flow	1.753 [0.0768]	1.00467	519	42.2	12.3
Low Temp	2.503 [0.0197]	1.00635	460	41.5	13.6
Low Density	2.503 [0.0197]	1.00128	523	40.6	14.1
DYE STUDY No. 2					
Mean Flow	3.062 [0.1342]	1.00467	403	42.3	13.1
Max Flow	4.792 [0.2101]	1.00467	381	41.1	15.2
Min Flow	2.015 [0.0883]	1.00467	425	43.3	11.5
Low Temp	3.062 [0.1342]	1.00635	375	42.6	12.9
Low Density	3.062 [0.1342]	1.00013	470	41.2	13.6

correspond to trapping depths of approximately 130 to 140 feet below the water surface. The dye study data (CH2M HILL, 1993) generally agree with the model predictions for both dilution and trapping depth, although dilutions observed were typically higher than predicted by the model (the model appears somewhat conservative overall by predicting lower than expected dilutions). Lower dilutions than the model predicted average dilutions were occasionally detected during the first dye study at the plume trapping depths (Table 3-3 in CH2M HILL, 1993). However, these dilutions are considered to be representative of individual plume centerline dilutions, as described in the dye study report (CH2M HILL, 1993). Examination of the model output indicates that if centerline dilutions are considered, the model predicts lower dilutions than observed and the model is somewhat conservative for centerline dilution as well as for average dilution.

- **For the tradewind dye study:** the model predicts dilutions of about the same or slightly lower than for the nontradewind season with the effects of higher effluent flow rates and larger density differences offsetting the effects of higher ambient current speeds. Predicted trapping depths are about the same or slightly deeper than for the nontradewind conditions. The initial dilutions (average and centerline) follow the same trend as described above for the nontradewind case. The model appears to be somewhat conservative and observed initial dilutions are typically higher than those predicted. However, the trapping levels are not in agreement. During the second dye study the plume was observed to be at or near the surface. Examination of the field data and detailed model output do not directly explain this inconsistency. We attribute it to vertical advection induced by the reef wall under the prevailing circulation during the time of the study. This phenomena is discussed in more detail below.

As described above the UDKHDEN model predictions appear to be conservative except for the discrepancy in trapping depth observed during the tradewind season. This is most likely a result of vertical currents near the reef wall that is located just to the north of the diffuser. Under particular wind conditions these currents may be upwelling or downwelling. During the tradewind study upwelling currents, combined with a very weak density gradient, would explain the location of the plume higher in the water column than expected. The plume may dilute and reach a trapping level near the predicted depth. Subsequently weak vertical (upwelling) currents could move the plume upward in the water column. The water column is virtually unstratified, particularly in the upper portion, so the movement of a neutrally buoyant plume would be easily induced by even very weak upwelling currents. This appears to have been the situation during the second dye study. This behavior of the plume is supported by field observations that indicate the minimum dilutions occurring over a wide range of depths, consistent with the slow upwelling described above.

SUBSEQUENT DILUTION

The subsequent dilution model (CDIFF) was run using input based on the field data and the result of the UDKHDEN model predictions. The subsequent dilution model was run based on the initial dilution model results for the mean flow for each dye period. However, the concentration at the beginning of subsequent dilution was taken as 100-percent and the initial dilution was input as 1:1, so that the results could be applied to any of the initial dilution cases. In addition, to investigate model sensitivity and the range of potential scenarios, the model was run under a number of assumptions for each dye study case as follows:

[1] Assuming an initial width four times the size of the individual plumes from each diffuser port and using the surface current speed

[2] Assuming an initial width of a single plume from one diffuser port and using the surface current speed

[3] Assuming an initial width four times the size of the individual plumes from each diffuser port and using the current speed at the predicted trapping depth

[4] Assuming an initial width of a single plume from one diffuser port and using the current speed at the predicted trapping depth

In all cases the plume is assumed to move parallel to the shoreline and the shoreline is assumed to be the location of the reef wall. Results of the subsequent dilution model predictions are summarized in Table 2-5. Detailed model output is given in Appendix II.

The model predicts centerline dilution which is one-half the average dilution across the plume. The most realistic of the cases stated above provide the following results:

- **For the nontradewind dye study:** the initial dilution is complete prior to plume merging (or just at the time of merging for the maximum flow case) and the plume was observed at the trapping level indicated based on field observations. Therefore, the plume behavior is best indicated by case [4] above, and case [3] would be overly conservative. Centerline subsequent dilutions for these cases are 2.1 and 4.9 at the edge of the mixing zone, for cases [3] and [4] respectively. This would correspond to total dilutions (average) of between 2000:1 and 4700:1 at the mixing zone boundary (taken to be 1300 feet from the diffuser. Field observations during the dye study indicated that dilutions of this magnitude occurred well before the mixing zone boundary. This implies that case [4] is more realistic, but still conservative.

- **For the tradewind dye study:** the initial dilution is consistently achieved before the plumes merge. Under some conditions, however, the plume is observed to approach the surface rather than remain at the trapping level predicted by the model. Therefore the behavior is best predicted by cases [2] and [4] with case [2] expected to be somewhat conservative (prediction lower than expected dilutions). Centerline subsequent dilutions for these cases are 2.3 and 4.4 at the edge of the mixing zone. This would correspond to a total

Table 2-5: Subsequent Dilution Predictions			
CASE	Distance from Diffuser (feet)	Subsequent Dilution (Average)	Total Dilution (Average Flow)
Dye Study No. 1 - Nontradewind Conditions			
[1] Mean Effluent Flow, Combined Plume, Surface Current	1300	2.8	1360
	450	2.0	970
[2] Mean Effluent Flow, Single Plume, Surface Current	1300	5.2	2520
	450	2.7	1310
[3] Mean Effluent Flow, Combined Plume, Current at Trapping Depth	1300	4.2	2040
	450	2.3	1120
[4] Mean Effluent Flow, Single Plume, Current at Trapping Depth	1300	9.8	4750
	450	3.7	1790
Dye Study No. 2 - Tradewind Conditions			
[1] Mean Effluent Flow, Combined Plume, Surface Current	1300	2.6	1050
	450	2.0	810
[2] Mean Effluent Flow, Single Plume, Surface Current	1300	4.6	1850
	450	2.5	1010
[3] Mean Effluent Flow, Combined Plume, Current at Trapping Depth	1300	3.8	1530
	450	2.3	930
[4] Mean Effluent Flow, Single Plume, Current at Trapping Depth	1300	8.8	3550
	450	3.5	1410

average dilution of between 1800:1 and 3500:1 at the mixing zone boundary. Field observations during the dye study indicate that these values are typical of the worst cases observed and are lower than the large majority of observations.

The mixing zone is area within 1300 feet of the diffuser, except along the reef where the mixing zone boundary is defined as the 30-foot contour. The closest distance to the diffuser is about 450 feet. In the case of the surfacing plume during the tradewind dye study, the model predicts that dilutions will be between 1000:1 and 1400:1 for worst case conditions (single plume, cases [2] and [4] above). Observations during the dye study indicate that the dilutions in the vicinity of the reef are greater than these values. The model predictions appear to be conservative in all respects.

Section 3

WASTEFIELD TRANSPORT

Numerical model predictions used to define the ZOM addressed the long-term effects of the discharge on the ambient TN and TP levels throughout the harbor as well as the dilution and dispersion near the diffuser discussed above. The long-term processes determine the average levels of the effluent constituents in the ambient receiving water of the harbor. The ambient water is the diluting water for the initial and subsequent dilution process. For an enclosed bay, such as Pago Pago harbor, the ambient concentrations are affected by the effluent discharge levels. Therefore, ambient levels as a function of discharge loading must be accounted for to calculate constituent concentrations resulting from the initial and subsequent dilution processes. Ambient levels must also be used to determine, or predict, compliance with american Samoa Water Quality Standards (ASWQS: [ASG, 1989]) throughout the harbor.

Verification of the previous model predictions includes verifying predictions of long-term ambient constituent levels for the relocated cannery discharge through the JCO. Model predictions are verified by comparison of model predicted concentrations with concentrations measured during the water quality monitoring program. If the model is not adequately verified, new predictions must be developed based on recalibrated models.

The applications of the model that were conducted to verify previous predictions, and comply with the NPDES permit conditions, are described below. The overall approach to predict ambient concentrations, a description of the TN and TP loadings used in the model, a summary of model results, and an evaluation of the model verification are presented below. Brief descriptions of the wastefield transport model used are included in the discussions below with references provided for more detailed technical.

PREDICTED AMBIENT CONCENTRATIONS

Previous predictions of ambient conditions in Pago Pago Harbor due to the operation of the JCO used a wastefield transport model (PT121). This model is described in more detail in the study plan (an addendum to this report) and in the feasibility study (CH2M HILL, 1991a). The model, developed by CH2M HILL, was based on a model originally developed by HRI (1989) for a wasteload allocation study of Pago Pago Harbor. The results were presented as a series of contour plots of TN and TP concentrations for a range of discharge loadings and alternative outfall sites (CH2M HILL, 1991a).

Since the time the outfall became operational, water quality data have been collected by ASG. Effluent chemistry and flow data have been collected by each of the canneries. These data are used below to verify the ambient concentrations predicted using PT121. The effluent chemistry and flow data provided by the canneries are used for input to the same model developed for, and used in, the previous studies. Long-term average TN and TP loadings from the canneries are calculated based on approximately one year (13 months) of recorded flow and effluent chemistry data. The results of these model runs are compared to the long-term average concentrations obtained from the ASG water quality data for the same time period.

TN AND TP LOADINGS

The effluent flow and chemistry data provided by StarKist and VCS which were used to generate long-term average loadings are included as Appendix III. The long-term average TN and TP loadings were based on records made between May 1992 and June 1993. These data correspond to the period of available water quality data collected by ASG following the beginning of operation of the JCO. A start data of May 1992 is appropriate as the JCO started operation in February 1992. The three month period should be sufficient to allow the ambient TN and TP concentrations to come to equilibrium with the new discharge location. The average flows and loadings for each cannery as well as the combined averages for the JCO are shown below in Table 3-1.

Table 3-1. Long-Term Average Loadings from the JCO.

Facility	Flow (mgd)	Total Nitrogen (kg/day)	Total Phosphorus (kg/day)
Starkist Samoa, Inc.	1.24	368	25
VCS-Samoa Packing	0.56	308	62
JCO (combined)	1.80	676	87

MODEL RUNS

Figure 3-1 shows the PT121 model grid used for modeling TN and TP concentrations in Pago Pago harbor. The model grid shown is the same as used in the initial predictions for the feasibility study as described above. Detailed technical descriptions of the model can be found Appendix C of the feasibility

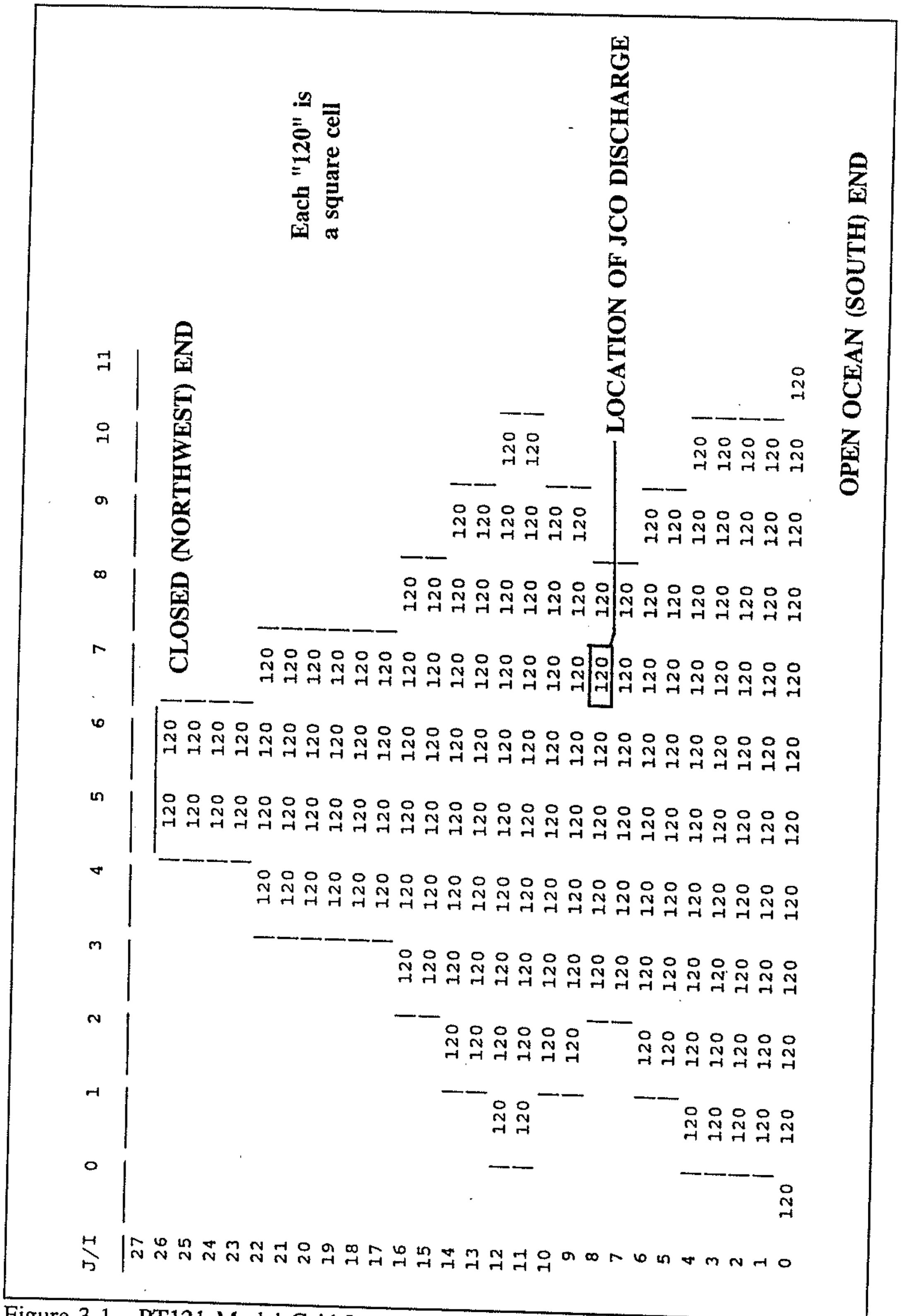

Figure 3-1. PT121 Model Grid Layout

study (CH2M HILL, 1991a). Modifications were made to the PT121 input files used in the feasibility study only for the following reasons:

- To reflect the measured loadings from the JCO for the time period of May 1992 through June 1993,

- To reflect the location of the JCO diffuser in the outer harbor (cell [7,8] in Figure 3-1), and

- To account for variability in background levels from those used in the previous study.

The TN and TP loadings used in the previous study were replaced with the average flow and loads shown in Table 1. The location of the discharge point was as shown on Figure 3-1. Background levels for TN (120 mg/m^3) and TP (13 mg/m^3) as used in the original feasibility study, were used for the model runs described below. However, additional model runs were made using background concentrations of 100 mg/m^3 for TN and 14 mg/m^3 for TP. These levels were representative of average levels measured outside the harbor (Station 5 in Figure 3-4) during the recent harbor water quality measurements described below.

Appendix IV presents model output for each of the cases run. The output presented includes initial conditions and conditions at the end of each model run. The model was run to a steady state condition to reflect long term average conditions. Figures 3-2 and 3-3 present contour plots of the calculated long-term concentrations for TN and TP for the original and revised background concentrations, respectively.

MODEL VERIFICATION

The water quality data for Pago Pago Harbor used in this study was collected during eight sampling events between May 5, 1992 and June 22, 1993. For each event, two samples were collected at each station: one at a depth of 3 feet and the other at a depth of 60 feet. Figure 3-4 shows the locations of the ASG water quality monitoring stations used to verify the model results. The stations shown in Figure 3-4 (Stations 5 through 13) are the original monitoring stations where data have been collected since 1984 (the pre-JCO data were summarized by CH2M HILL [1991a, 1991c]). Additional stations (Stations 14 through 18) were established near the boundaries of, and within, the ZOM by the existing NPDES permits and have been monitored since shortly after discharge through the JCO began. The additional stations are discussed in more detail below in Section 5. The water quality data for the period considered for this report are tabulated and included as Appendix V.

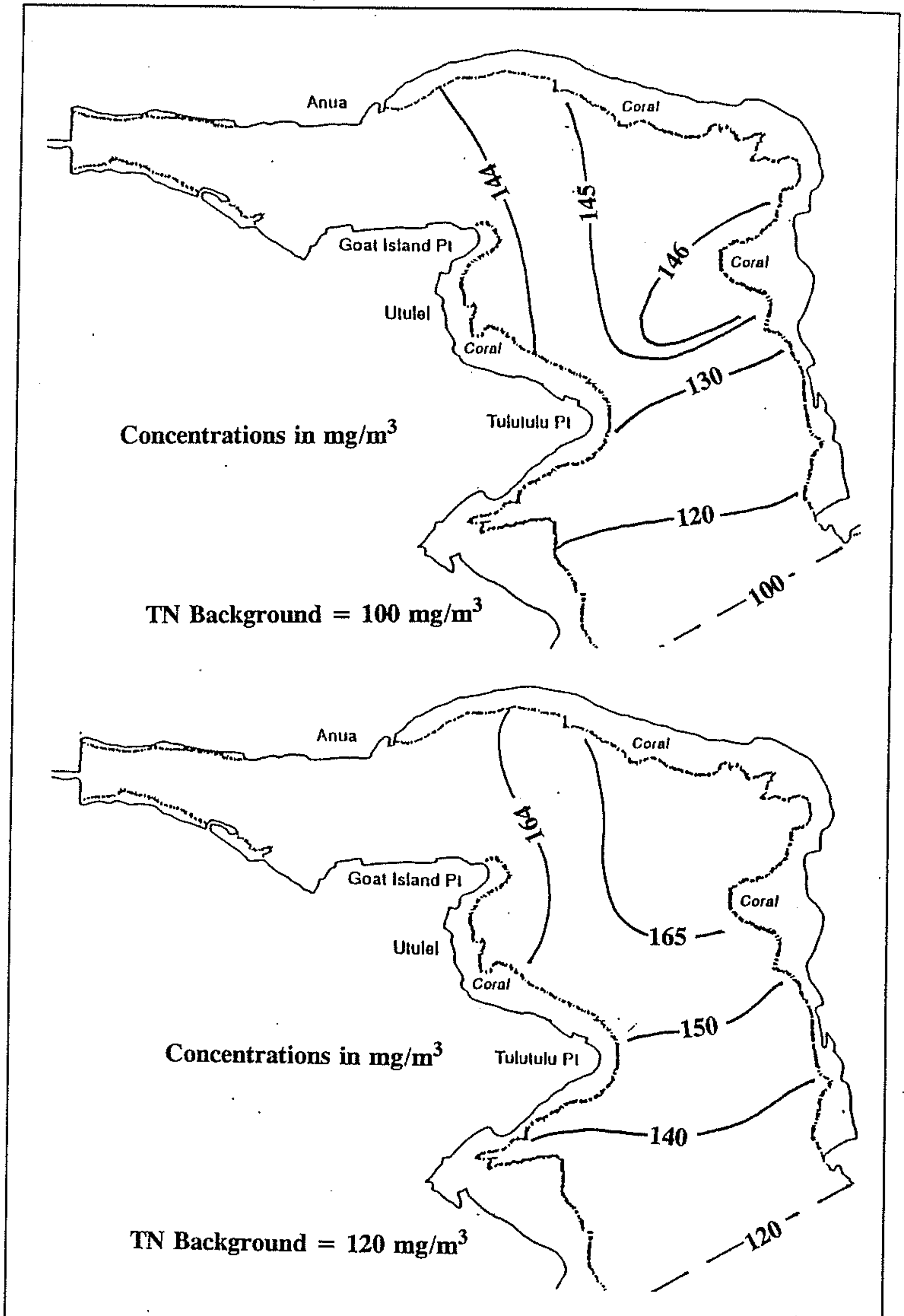

Figure 3-2. Contour Plots of TN for JCO Discharge.

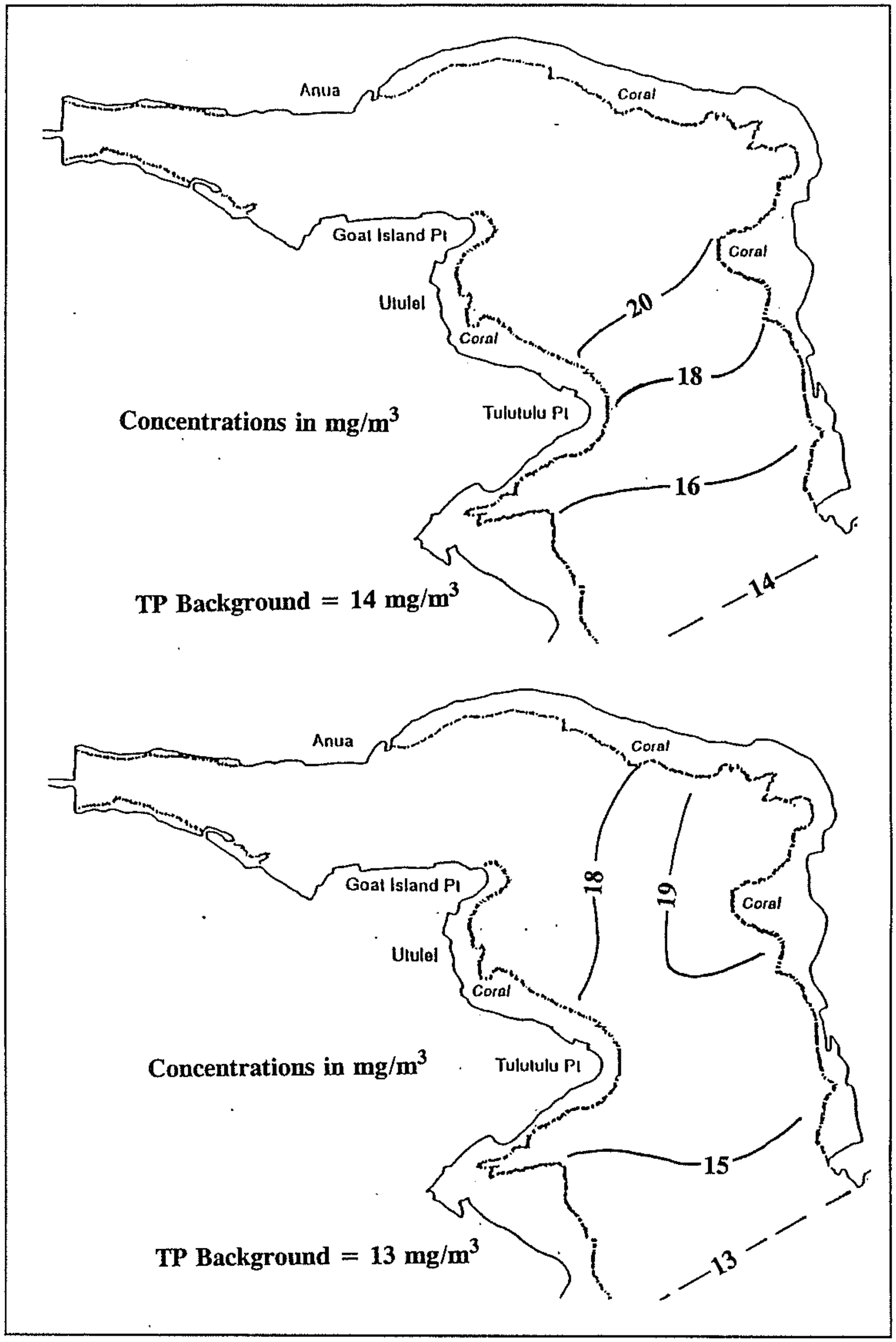

Figure 3-3. Contour Plots of TP for JCO Discharge

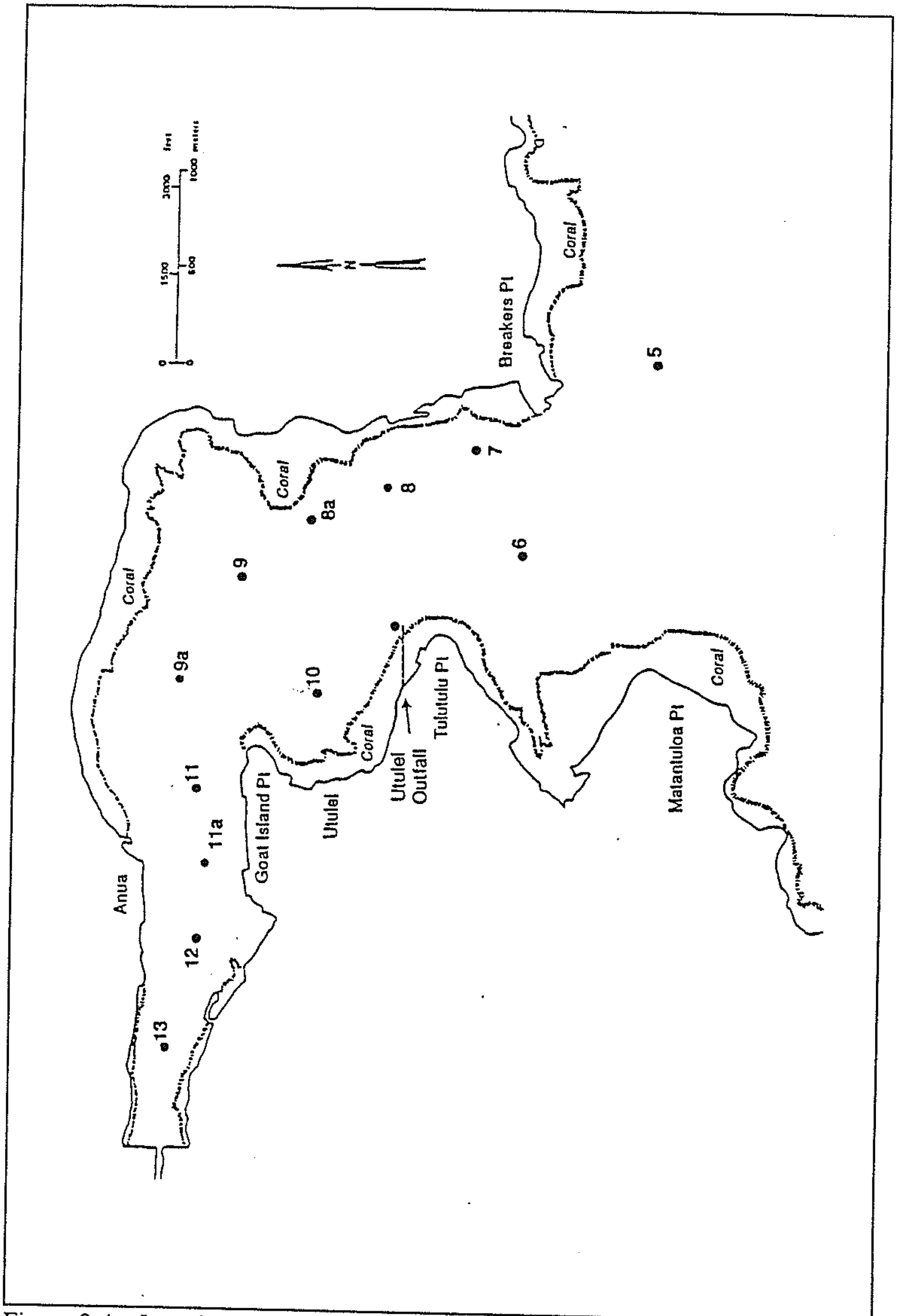

Figure 3-4. Locations of ASG Water Quality Sampling Points

The average TN and TP concentrations predicted by the model, and the concentrations measured by ASG during the study period, are presented in Tables 3-2 and 3-3, respectively. Figures 3-5 and 3-6 show measured and predicted concentrations plotted as a function of distance from the mouth of the harbor. The figures include observed data for the ZOM stations (Stations 14 through 18). The tables include only comparisons for observations outside the ZOM, since it is data from these stations that were used to develop the model. The complete data set is provided in Appendices IV and V.

Examination of the water quality data indicates that the values for TP for the August 1992 monitoring included some unusually high values at Stations 14 and 16 (within the ZOM). If the observed data for the August 1992 monitoring is removed from the averages for each station shown in Figures 3-5 and 3-6: the predictions for TP is noticeably improved and, the prediction for TN is slightly worse. As shown in the tables and figures the model adequately reproduces the observed levels of both nitrogen and phosphorus as described below.

Table 3-2. Modeling Results vs. Measured Values, Total Nitrogen.

Sampling Station Number	PT121 Model Grid Numbers		Measured TN (mg/m^3)			Model Results	
	Row	Cell	Max.	Min.	Average	0.100 mg/m^3 Background	0.120 mg/m^3 Background
5	---	---	0.162	0.048	0.103	---	---
6	5	5	0.192	0.038	0.118	0.129	0.146
7	6	8	0.165	0.073	0.127	0.131	0.162
8	7	7	0.187	0.038	0.120	0.142	0.162
8a	9	7	0.214	0.100	0.145	0.149	0.159
9	12	8	0.180	0.086	0.131	0.145	0.158
9a	14	6	0.193	0.080	0.126	0.145	0.157
10	11	3	0.259	0.058	0.131	0.144	0.157
11	17	5	0.237	0.095	0.146	0.144	0.157
11a	19	5	0.221	0.065	0.137	0.144	0.157
12	21	6	0.229	0.062	0.151	0.143	0.156
13	24	6	0.302	0.071	0.188	0.143	0.155

Table 3-3. Modeling Results vs. Measured Values, Total Phosphorus.							
Sampling Station Number	PT121 Model Grid Numbers		Measured TP (mg/m^3)			Model Results	
	Row	Cell	Max	Min.	Average	0.013 mg/m^3 Background	0.014 mg/m^3 Background
5	---	---	0.025	0.006	0.014	---	---
6	5	5	0.027	0.002	0.014	0.016	0.018
7	6	8	0.027	0.008	0.015	0.018	0.018
8	7	7	0.026	0.010	0.017	0.018	0.02
8a	9	7	0.034	0.009	0.019	0.018	0.02
9	12	8	0.031	0.011	0.018	0.018	0.02
9a	14	6	0.029	0.009	0.016	0.018	0.02
10	11	3	0.028	0.009	0.014	0.018	0.02
11	17	5	0.031	0.009	0.018	0.018	0.02
11a	19	5	0.046	0.008	0.018	0.018	0.02
12	21	6	0.028	0.007	0.018	0.018	0.02
13	24	6	0.058	0.008	0.028	0.017	0.02

Total Nitrogen (Outside ZOM). Using the concentration values at the entrance to the harbor based on the observations for the period of interest (100 mg/m^3), the model somewhat over predicts the concentrations of TN throughout the harbor, except for the two stations in the far inner harbor. We attribute the underprediction at the inner harbor stations (Stations 12 and 13 in Figure 3-4) to a source of nitrogen in the inner harbor not accounted for by the model. This source is probably from runoff delivered by streamflow into the inner harbor. This conclusion is supported by examination of the observed nitrogen concentrations. It is physically impossible for the reversal in concentration gradient in the inner harbor to be caused by discharge from the JCO. An inner harbor source is the only reasonable explanation. Therefore, we conclude that the model is conservative (over predicts the concentrations resulting from the JCO discharge).

Total Phosphorus (Outside ZOM). Using the values at the entrance to the harbor based on the observations for the period of interest (14 mg/m^3), the model over predicts the concentrations of TP throughout the harbor except for the innermost station. As in the case of TN described above, we attribute the underprediction at the inner harbor stations (Station 13 in Figure 3-4) to a source of phosphorus in the

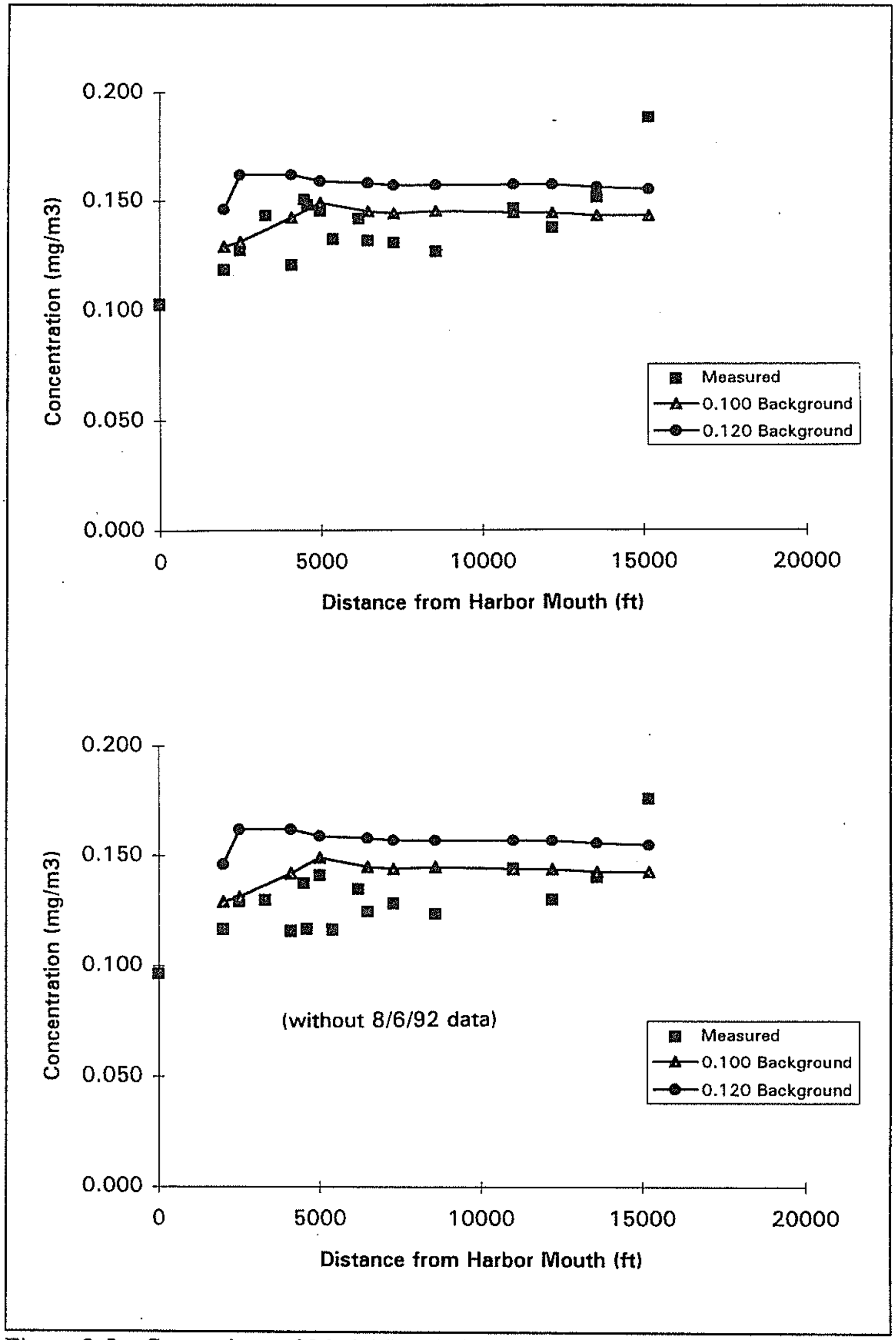

Figure 3-5. Comparison of Model Predictions and Observations for TN

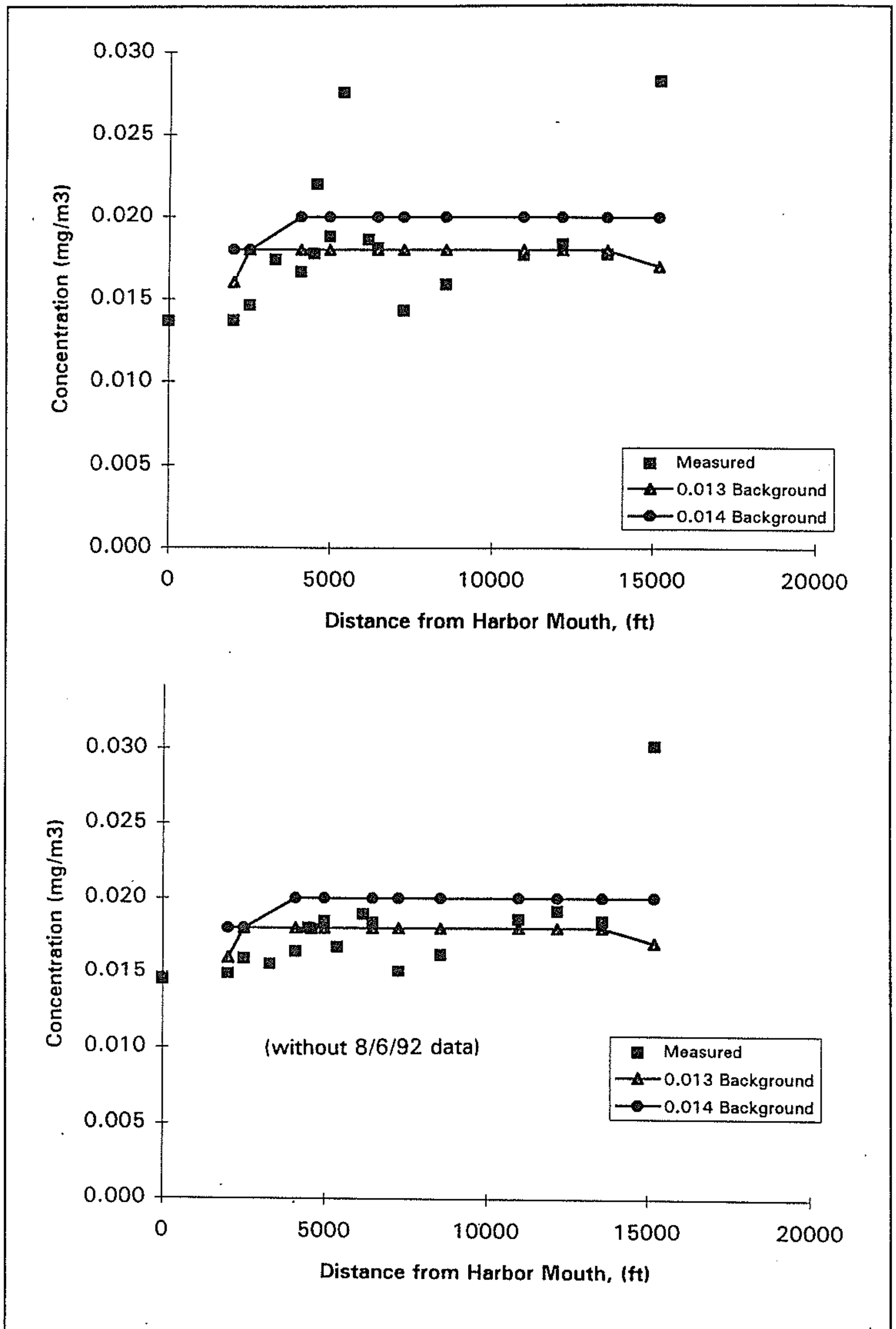

Figure 3-6. Comparison of Model Predictions and Observations for TP

inner harbor not associated with the JCO discharge. Therefore , as in the case of nitrogen, we conclude that the model is conservative (over predicts the concentrations resulting from the JCO discharge).

TN and TP Inside ZOM. The wastefield transport model results within the mixing zone are used as the ambient concentrations on which the initial and subsequent dilution model results were superimposed to develop the ZOM dimensions. The wastefield transport model results within the ZOM are included in the model output (Appendix IV). An evaluation of the mixing zone is provided in the Results section (Section 5) below. The intent of the model verification exercise, described above, was to examine model predictions throughout the harbor. It is clear from the data presented that the model is somewhat conservative and performs as expected.

Section 4

BOD IMPACTS

This section addresses the impacts of BOD discharge from the Joint Cannery Outfall on the dissolved oxygen concentrations in Pago Pago Harbor. The available data are not adequate to fully calibrate a model and perform a simulation that is predictive on small time and space scales. However, the available data are adequate to do a detailed screening level evaluation of the impacts. Therefore, the evaluation conducted and presented below addresses long term average impacts for major sections of the harbor. This evaluation was conducted in a conservative fashion to determine if there was any basis for concern about BOD impacts in the Harbor. More detailed model verification studies can be done for the subsequent model verification study reports, as described in the Results and Conclusion Section (Section 5) below.

APPROACH

The approach used for the evaluation of BOD impacts, as indicated above, was to do a screening level approach to determine the approximate magnitude of impacts. This approach includes the assessment of extreme worst case scenarios to estimate an upper bound to the potential impacts. The evaluation, and model simulations used, considered only the possible impacts from the JCO.

The model used for the evaluation was the same model, PT121, described above and used for the evaluation of nutrient discharges from JCO. Based on the descriptions in the Wastefield Transport Section (Section 3) above, the model has been verified for application to Pago Pago Harbor and the JCO discharge for conservative substances. For the evaluation of BOD impacts, the model is used to account for the nonconservative decay of BOD as a first order decay process. The model code was modified to account for the reduction in DO concentration as a result of the decay of BOD. In addition, a reaeration routine was added to the model for use in DO calculations. The basic model was described above and in more detail in the original feasibility study (CH2M HILL, 1991a). The primary changes made to the model for the BOD-DO evaluation include:

- An additional model control flag was added to indicate when BOD-DO simulations were to be executed

- The calculation scheme was modified so that, when BOD-DO simulations are executed, the model makes two calculations passes through the spatial grid at each time step: [1] the first pass calculates changes in BOD concentration in each cell as a result of cell volume change, advection, diffusion, input (via point source and non-point source discharges), and decay; [2] The second pass calculates the changes in DO concentration as a result of cell volume changes, advection, diffusion, input (via point source discharges), input (via reaeration), and decay (via BOD exertion).

- Input of a reaeration coefficient, a point source DO loading (DO of effluent), and a representative DO saturation value were added to the model water quality parameter input file.

- Output of both BOD and DO concentrations is done when the BOD-DO simulation is executed.

The revised mode source code is provided in Appendix VI. The model does not account for DO production or demand from any other sources (discharges, runoff, or biological processes). The evaluation using the model is done only to estimate the impact of JCO discharge of BOD. Therefore, the model is not a predictor of DO concentrations but only a predictor of changes in DO that are attributable to the discharge. Therefore, there is no additional rigorous calibration procedure for the model when run in the BOD-DO mode. Of course, the model has been calibrated, and verified, as adequately representing the transport (advective and diffusive) processed for TN and TP as described earlier. This means that there is a good degree of confidence in the ability of the model to provide, at least, screening level predictions of BOD impacts of the JCO discharge. The results of the model were compared to DO field measurements to determine if the results appear reasonable.

PARAMETER SELECTION

The use of the wastefield transport model for evaluation of BOD impacts requires the selection of values for a number of parameters. These include the loadings to be used, the initial conditions, the open boundary conditions, and the additional input parameters added to the model for BOD-DO simulations as described above. All other model parameters and variables are the same as previously described for the simulation of TN and TP loadings. The values used for each of the parameters required is described below.

BOD Decay Rate

The decay rate of BOD, which is also used as the BOD exertion on DO, can be measured directly or based on typical values. The approach for this study was to use typical values. This will provide a reasonable estimate and the worst case analysis describe below will provide the additional confidence in the screening level estimates of BOD impacts. The available data is in terms of five day BOD (BOD_5).

The ultimate BOD (BOD_U) was calculated as 1.46(BOD_5). This is a typical and accepted value for wastewater. The decay of BOD was taken as a first order decay process described by:

$$R_O = k \cdot C_B$$

where:

R_O = the rate of deoxygenation (rate of decrease of BOD and DO),
k = the first order reaction-rate constant,
C_B = the concentration of BOD.

The integrated form of this equation is the familiar express for first order decay

$$C_B = (C_B)_{t=0} \cdot \exp(-kt)$$

where:

$(C_B)_{t=0}$ = the initial concentration of BOD (at time(t) = 0).

The reaction-rate is a function of temperature, typically expressed as:

$$k = k_{20} \cdot (\theta_T)^{T-20}$$

where:

k_{20} = the reaction-rate constant at 20 °C = 0.23/day,
θ_T = the temperature coefficient = 1.047,
T = temperature in °C.

A range of values of k_{20} and θ_T are reported in the literature. For wastewater, typical values are as given as in the definitions above (Tchobanoglous, 1987). Using these values, at a worst case (high) harbor water temperature of 30 °C, yields a BOD reaction-rate constant of 0.364 per day. This is the value used in the model.

The approach described above assumes that the BOD reaction-rate constant is indeed constant. It is known from previous experiments with the effluent (CH2M HILL, 1994b) that there is an immediate dissolved oxygen demand (IDOD) that appears to peak rapidly at about 10 to 14 hours after discharge. This phenomenum is seen in the laboratory (and bioassay procedures must account for it) but it is not known whether it would appear in the natural environment. However, the rapid initial and subsequent dilution of the discharge plume will tend to mask any effect of the IDOD in the receiving waters (CH2M HILL, 1994b). The use of a constant reaction-rate constant is considered appropriate and sufficient for the modeling described below.

Dissolved Oxygen Reaeration

The dissolved oxygen is input to the harbor by photosynthesis and removed by respiration of the organisms in the harbor. As described above, these processes are ignored here since only the impact of BOD from the outfall is being considered. In addition, these process vary diurnally, which is on a time scale not considered by the model. However, DO is also input to the harbor by reaeration (atmospheric exchange), which is considered in the model. The rate of oxygen input is estimated by:

$$R_R = k_R \cdot (C_S - C_O)$$

where:

- R_R = the rate of reaeration (oxygenation) (rate of increase of O_2),
- k_R = the first order reaeration-rate constant,
- C_O = the concentration of DO.
- C_S = saturation value of oxygen

An integrated form of this equation is similar in form to that given above for BOD decay. The reaeration rate is a function of temperature expressed as:

$$k_R = k_{R@20} \cdot (\theta_T)^{T-20}$$

where:

- $k_{R@20}$ = the reaction-rate at 20 °C,
- θ_T = the temperature coefficient = 1.024,
- T = temperature in °C.

A range of values of k_{20} and θ_T are reported in the literature (Tchobanoglous, 1987). For wastewater, a typical value for θ_T ia as given as in the definition above. The value of $k_{R@20}$ varies depending on a number of physical factors including wind speed, current speed, and other factors that particularly relate to turbulence and mixing at and near the air water interface. Values for surface waters range from 0.1/day or smaller for small stagnant ponds to greater than 1.15/day for rapids and waterfalls. Typical values for estuaries are often in the range of 0.2 to 0.6 per day. A value of 0.29/day for Pago Pago Harbor is considered conservative and is used in some of the model runs described below (at 30 °C this is equivalent to 0.368/day).

As described above, the reaeration rate is limited by the saturation value of DO, which is in turn a function of temperature and salinity. DO saturation is inversely proportional to both temperature and salinity. A worst case is representative of 35 ppt salinity and 30 °C, since these values represent the approximate upper bound of both parameters. The value of DO at saturation used, consistent with the worst case, was 6.22 mg/l.

Effluent DO

Dissolved oxygen levels in the effluent discharge were assumed to be zero for the model input. The DO levels are known to be very low, therefore the use of zero is a good approximation.

Initial and Boundary Conditions

Initial conditions include the concentrations of BOD and DO in the harbor at the beginning of the model simulation. Initial conditions set in the model are simply a convenient starting point and the final model results, at steady state, will be the same regardless of the initial conditions. The model results of interest are the concentrations achieved at steady state (for a constant input) and the selection of initial conditions close to the steady state value will reduce the model run time needed. Therefore, based on preliminary model tests and review of the available data, and initial condition of 6.0 mg/l of DO was selected. Since, the model simulations are intended to look only at the effect of cannery discharge, the initial conditions of BOD throughout the harbor were set at 0 mg/l. This is consistent with the boundary conditions described below.

The boundary conditions for DO and BOD concentrations at the open (ocean) boundary are important parameters. As described above, to look at the effect of BOD loadings from the canneries only, a boundary condition of zero BOD at the ocean boundary is appropriate. Otherwise, oxygen demand from other sources is introduced. This boundary condition (BOD = 0) results in predictions of steady state BOD concentration throughout the harbor that are attributable only to the canneries discharge.

The boundary condition for DO at the ocean boundary was set at 6.0 mg/l (just below saturation). The available data for Station 5 (see Figure 3-4) indicate that the DO is generally saturated at the surface and very close to saturation at depth. Although there is only limited data for the deeper portions of the water column at the harbor entrance, the depth is within the normal range of the mixed layer in the open ocean and the DO levels are expected to be at or near saturation.

BOD Loadings

The time frame of the BOD impact evaluation is selected as the same used for the TN and TP model verification (May 1992 through June 1993). This provides a high level of confidence that the model is simulating the physical processes (diffusion and advection) in the harbor accurately. Complete records of BOD loadings from the canneries for the time frame used in the wastefield transport verification (Section 3) were not available. However, given the range of conditions used for the model simulations described below, only a reasonable estimate is required. The basis for the estimate is given in Appendix III. Table 4-1 summarizes the BOD loadings used as the nominal case for the model simulations.

Table 4-1. Summary of BOD Loadings for Nominal Case Model Simulation

Source	BOD_5 Concentration (mg/l)	Average Flow (mgd)	BOD_u Loading kg/day
Samoa Packing	1,487	0.56	4,600
StarKist Samoa	304	1.24	2083
TOTAL			6684

PREDICTED IMPACTS

The investigation of potential BOD impacts was done in three steps: model simulation of the nominal discharge case as defined above, model simulation of extreme worst case scenarios, and comparison of model simulations to available filed data during the same time period. Each of these steps in the evaluation is described below. In addition, the limitations of the approach used were considered and are discussed below. The results and conclusions based on the evaluation are discussed in more detail in Section 5 below (Results and Conclusions).

Physical and geometric data were identical to that used for the Wastefield Transport verification described in Section 3 and is the same as used for the original Feasibility Study to select the outfall location (CH2M HILL, 1991a). If there were no discharge of BOD the model, as set up and executed, would eventually predict DO levels somewhere between saturation (maximum possible) and the boundary condition (minimum possible). These levels of DO concentration are shown in Figure 4-1, for each cell of the model grid, and provide a reference value with which to compare the results from other simulations.

In all cases the simulation was run to steady state. Preliminary runs indicated that steady state is achieved within 30 to 50 days. Simulations were run for at least this

BOD - DISSOLVED OXYGEN SIMULATION FOR PAGO PAGO HARBOR
Model Run No. 5 - Reference Case - Nominal Kr (0.00528/hr)
BODu = 0000 kg/day - K = 0.0152/hr - Diffusivity @6000 & 26000 m^2/hr)

Table of Dissolved Oxygen Concentrations in mg/l

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						6.12	6.12					
25						6.12	6.12					
24						6.13	6.13					
23						6.14	6.14					
22					6.14	6.14	6.14	6.14				
21					6.14	6.14	6.14	6.14				
20					6.14	6.14	6.14	6.14				
19					6.14	6.14	6.14	6.14				
18					6.14	6.14	6.14	6.14				
17					6.13	6.13	6.13	6.13				
16				6.12	6.12	6.12	6.12	6.12	6.12			
15				6.12	6.12	6.12	6.12	6.12	6.12			
14			6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12		
13			6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11		
12		6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	
11		6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	
10			6.11	6.10	6.10	6.10	6.10	6.10	6.10	6.10		
9			6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10		
8				6.09	6.09	6.09	6.09	6.09	6.09			
7				6.08	6.08	6.08	6.08	6.08	6.08			
6			6.07	6.08	6.07	6.07	6.07	6.07	6.07	6.07		
5			6.06	6.07	6.07	6.07	6.06	6.06	6.06	6.06		
4		6.05	6.06	6.06	6.06	6.06	6.05	6.05	6.05	6.05	6.05	
3		6.04	6.05	6.05	6.04	6.04	6.04	6.04	6.04	6.04	6.04	
2		6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	
1		6.02	6.02	6.02	6.02	6.02	6.02	6.02	6.02	6.02	6.02	
0	6	6	6	6	6	6	6	6	6	6	6	6

Figure 4-1. Reference Case Values of DO in each Model Cell

long. Preliminary runs were made for over 100 days. Tidal variations in BOD varied by 10 to 20 percent in the shallow cells and only 1 to 2 percent in most of the harbor. Tidal variations in DO were found to be quite small (a few percent) and were not considered in presentation of the results below.

The nominal case uses the variables and parameters as described above for reaction-rate constants and saturation values of DO. This is a conservative evaluation since the reaeration reaction-rate coefficient is probably less than the expected natural value in the harbor. The results of the nominal case run indicate that the impact of BOD loadings representative of the cannery wastewater as described above are on the same order as tidal variations throughout the harbor. This level of impact probably cannot be measured with typical field instruments. A more conservative nominal case with a $K_{R@20} = 0.1$ was also run. This case results in a predicted impact (decrease) of about 0.1 mg/l in the inner harbor and less in the outer harbor. The results for these cases are summarized in Table 4.2 and BOD and DO concentrations in each model cell are provided in Appendix VII.

Two extreme worst cases were considered to determine the sensitivity of the system and to place a limit on the magnitudes of impacts that could reasonably be expected. These cases were: [1] a reduction of the reaeration reaction-rate coefficient (k_R) to zero with other parameters held the same as for the nominal case, and [2] an increase of BOD loading to 20,000 kg/day with other parameters held the same as for the nominal case. Both of these worst case scenarios are unrealistically conservative. However, these case provide a basis for examination of the sensitivity of the system to assumptions used in the screen model. The results, in terms of DO and BOD concentrations at each model cell are given in Appendix VII. The results are summarized in Table 4-2.

The case with zero reaeration indicates that the impact of the BOD discharge is on the order of 0.3 to 0.5 mg/l reduction in DO. This sets a limit on the impacts that could be expected from the loading input used. The effects would not be any greater than this. The case with the loadings at about three times the nominal indicates a decrease in DO levels throughout the harbor of about 0.15 mg/l.

The existing field data for DO during the time period of interest is presented in Table 4-3. This data was collected by ASEPA and represents DO values only for the surface layer. However, the data does appear to be in agreement with the model results that indicate little impact of the BOD discharge.

LIMITATIONS

As described in above, the evaluation for BOD impacts was done at a screening level. The model used was the most appropriate for the available data. The results

Table 4-2. Results of BOD Impact Simulations[1]					
Simulation Case	Reaeration Coefficient (k_R/day)	BOD Loading (kg/day)	Dissolved Oxygen Range (mg/l)		
			Inner Harbor	Middle Harbor	Outer Harbor
Reference	0	0	6.12-6.14	6.10-6.12	6.02-6.09
Nominal	0.368	6684	6.13-6.15	6.09-6.12	6.02-6.00
Nominal with Reduced k^R	0.126	6684	6.00-6.03	5.98-5.99	5.99-6.00
Extreme k_R	0	6684	5.65-5.53	5.65-5.73	5.78-5.79
Extreme BOD Loading	0.368	20000	6.01-6.10	5.96-5.99	5.97-6.00

[1] Impact is defined as the difference between the reference case and the simulation of interest.

indicate that the BOD discharge from the JCO has minimal impacts on DO in the Harbor for the existing outfall location. Impacts were probably of concern prior to high strength waste segregation when the discharge was in the inner harbor. For a realistic scenario, under present discharge conditions, it is likely that the impacts are probably not measurable. There are some limitations on the model that preclude exact quantitative descriptions of the impacts. These limitations include:

- The model is depth averaged. This means that vertical structure of DO cannot be evaluated. Since each cell is completely mixed at each time step, DO depressions at depth may be suppressed in the model but exist in the Harbor. Conversely, DO at the surface may be underestimated by the model for the same reason.

- The model is a farfield model and cannot predict or account for the behavior of DO in the plume. However, the initial dilution is so rapid, and is large enough, that any effect is probably small.

- The model has not been rigorously calibrated for BOD-DO simulations in terms of selection of reaeration and BOD decay coefficients based on field data.

Table 4-3. Observed DO Concentrations[1]			
Station[2]	Dissolved Oxygen (mg/l)		
	6 May 1992[3]	6 Oct 1992[4]	22 June 1993[5]
5	7.8	7.5	6.8
6	7.3	7.4	6.7
7	6.9	7.4	6.7
8	6.4	7.4	6.7
8A	6.0	7.0	6.6
9	5.8	6.7	6.6
9A	5.6	7.1	6.9
10	7.4	7.1	6.8
11	5.4	7.4	6.7
11A	5.1	7.0	6.6
12	4.6	7.4	6.8
13	3.4	7.6	6.7
14	6.1	7.4	6.7
15	5.9	6.9	6.8
16	6.3	7.4	6.6
17	5.8	8.0	6.7
18	7.0	7.4	6.6

[1]Data supplied by ASEPA.
[2]Station locations shown on Figure 3-4 and in Appendix VIII.
[3]Saturation values based on reported temperatures and estimated salinities are estimated to be between 6.3 and 6.6 mg/l.
[4]Saturation values based on reported temperatures and estimated salinities are estimated to be between 6.3 and 6.6 mg/l.
[5]Saturation values based on reported temperatures and estimated salinities are estimated to be between 6.4 and 6.7 mg/l.

- The model is a long term average model and does not account for diurnal variations in DO demand or input from biological sources.

The first three of the limitations listed above can not be addressed until additional data are available. Recommendations to address these points are provided in the Results and Conclusions Section (Section 5) below. The fourth point is not important in addressing the impacts of BOD, unless the DO conditions in the Harbor become impaired for reasons other than the cannery discharges, and the impact of cannery BOD loadings acts cumulatively to maintain the DO below ASWQS. This is not current the situation described by the available data.

Section 5

Results and Conclusions

This section of the report provides a brief description of the results of each of the three major modeling exercises described above and presents conclusions drawn from the results. Based on the model verification study, and the available water quality data, the location and design of the outfall and the definition of the ZOM are evaluated. Considering all of the material presented above recommendations for the following model verification studies are presented.

INITIAL AND SUBSEQUENT DILUTION MODELS

The initial dilution model, UDKHDEN, predictions agree well with the dye study observations. Care must be taken in running this model under very weak density gradients combined with bathymetric induced upwelling currents along the reef wall. Weak density gradients are likely during the tradewind season. The second dye study was done under the conditions of weak gradients and, during a portion of the dye injection period, the upwelling was observed. The model does provide accurate initial dilution calculations under these conditions, but the point of initial dilution must be determined from the detailed model output. The initial dilution number printed out by the program can not be used under these conditions.

The subsequent dilution model, CDIFF, appeared to be somewhat conservative. The initial dilution is complete prior to merging of plumes from individual ports. The individual plumes, after initial dilution is completed, do maintain integrity and the less intense subsequent mixing is described by the model.

Based on the analyses presented in Section 2, the major conclusions include:

- The initial dilution model (with the caveat described above) can be used to characterize the initial dilution process and is appropriate for determination of toxicity mixing zones.

- The subsequent dilution model can be used to estimate the concentrations of the plume after initial dilution. The use of an approach based on using concentration predicted by this model, superimposed on the long term average concentrations predicted by the wastefield transport model, to define the boundaries of the mixing zone appears to be justified.

The use of other initial and subsequent dilution models is not precluded (for example PLUMES or CORMIX). However, these models should be compared to and agree with the results of UDKHDEN simulations for the JCO discharge and the environmental conditions found in Pago Pago Harbor.

WASTEFIELD TRANSPORT MODEL

The wastefield transport model, PT121, was initially set up and calibrated for data based on the cannery discharges in the inner harbor. The model was then used to determine the appropriate location for the new discharge point and to predict ambient concentrations of TN and TP throughout the harbor. Using data based on the discharge at the new location the model predicts the observed concentrations of TN and TP throughout the Harbor very well, and is seen to bee somewhat conservative (predicts higher concentrations than observed). Since it is prudent to maintain some conservatism, it was not considered necessary to adjust diffusion coefficients or any other model parameters to maintain agreement with observations. The primary conclusions from this portion of the verification study include:

- The wastefield transport model, used to determine the location of the new outfall discharge, predicts the transport and concentrations of TN and TP for the new location as expected. A more sophisticated model is not necessary to evaluate the <u>overall</u> performance of the outfall and mixing zone.

- The model is more conservative for outer harbor discharge locations than initially indicated from calibration and verification based on inner harbor discharges. Therefore, the model simulations tend to under predict the admissible loadings for a given mixing zone geometry. Loadings higher than specified in the permit would still result in compliance with the ASWQS.

The wastefield transport model does have limitations in terms of describing fine scale spatial and temporal detail. The model has done a good job of evaluation the requirements for the location and design of the ZOM. However, any refined simulations of transport characteristics in more detail for the Harbor will require a more sophisticated model.

BOD-DO MODEL

The BOD-DO impact analysis was done as a screening level analysis using the verified wastefield transport model. This analysis provides a good indication of the overall impacts of BOD on the DO concentrations in the Harbor. Extreme worst case scenarios were considered to determine if there was any cause for concern. The result indicate that the impact of the loading from the JCO alone has a very small effect on overall harbor DO levels. The available data on BOD loadings and DO structure within the harbor are not sufficient to support detailed analyses of the DO dynamics in the harbor. Therefore, the vertical structure of the DO and the cumulative effects of all DO sources and sinks could not be considered. The major conclusions from this element of the study include:

- The results indicate that BOD loads consistent with expected JCO discharge levels will not have a measurable overall impact on DO in the harbor. Diffusion of BOD out of the harbor to the ocean, diffusion of DO into the harbor from the ocean, and reaeration are sufficient to nearly balance the DO demand from the cannery BOD loadings.

- Available data indicate that model predictions are consistent with the surface layer DO levels in the Harbor. There are no impacts from the outfall BOD loadings reflected in the surface layer.

The application of the wastefield transport model does have limitations, particularly in terms of prediction of nearfield impacts and accounting for vertical structure. Any nearfield impacts are expected to be in the lower part of the water column within the defined mixing zone area. Different models and more complete data for this part of the water column are required to assess the finer scale effects in this area of the Harbor.

EVALUATION OF THE ZONE OF MIXING

The model verification study presented above addresses the suitability of the models used to establish the diffuser design, the outfall location, and the ZOM. The study is essentially a test of the models as initially used in the Feasibility Study and the Mixing Zone Application (CH2M HILL, 1991b and 1991a). Based on the study results presented above, and the water quality data used for the study, the following conclusion about the performance of the outfall and the definition, of the ZOM can be stated:

- ***Toxicity Mixing Zone for Ammonia.*** The field data from the dye studies, and the subsequent model verification analyses, indicate that the diffuser is performing as initially predicted. Therefore, there is a high degree of confidence that the mixing zone for ammonia (based on a dilution of (80:1) is achieving the limited exposure time and spatial extent initially anticipated and predicted.

- ***Mixing Zone for TN and TP.*** The field data from the Receiving Water Quality Monitoring Program and the wastefield water quality transport model analyses indicate that the model predictions on which the ZOM definition was based were accurate.

Compliance with water quality standards throughout the harbor appears to have been generally attained, with some exceptions as noted below. Compliance with water quality standards for those parameters addressed by the original model predictions is currently as follows:

- ***Nutrients (TN and TP).*** TN and TP concentrations throughout the harbor are in compliance with the water quality standards (median not to exceed 200 μg/l and 30 μg/l for TN and TP, respectively) for the time period considered in this study (May 1992 through June 1993). The conclusion of compliance is based on the available data. TN and TP data are presented in Appendix V, and an expanded set of water quality data is provided in Appendix VIII. The data in Appendix VIII indicates the values that are above the numerical criteria.

  Appendix VIII also includes graphical presentations of TN and TP as functions of distance from the Harbor entrance and as a function of time for the various monitoring stations. The only area of concern is at Station 13 where the average (but not the median) values for the time period exceed the numerical criteria. This can not be directly attributed to the cannery discharge, and is probably driven by input from stream flow loadings.

  Appendix VIII also includes the data for February and March 1992. This is the time just after the outfall was relocated and provides an indication of the transition between inner harbor and outer harbor discharges. The data show the drop in TN and TP following relocation.

- ***Chlorophyll-a.*** Chlorophyll-a data for the time period of this study is presented in Appendix VIII. The chlorophyll-a data are not as complete as the TN and TP data but do show general compliance with the water quality standard (median not to exceed 1.0 μg/l) except at the inner harbor stations (11A, 12, and 13).

- ***Dissolved Oxygen and Turbidity.*** As above, the available data for the time period considered (Table 4-3 for DO, ASG data presented in Appendix VIII for turbidity) indicates the only potential area of concern is in the inner harbor. However, the overall dissolved oxygen and turbidity in the harbor appears to be in compliance with the water quality standards. As described above nearfield effects of the JCO discharge were not considered.

- ***Light Penetration.*** Light penetration can be crudely estimated by Secchi depth readings using an approximation $\chi = \kappa/D$, where χ is the extinction coefficient for visible light, κ is a constant, and D is the Secchi depth in meters (using a 30 cm Secchi disk). The constant κ has often been taken as 1.7 based on data from the English Channel (Sverdrup et al., 1942).

  The water quality standard is to achieve light penetration (1 percent of the incident light) at 65 feet 50 percent of the time. Calculations based on the above rough approximation, the water quality standard corresponds to a

Secchi depth of 24 feet (for a 30 cm disk). Examination of the data shows that the standard appears to be met except, possibly, in the inner harbor.

- *Ammonia and pH.* There is no data for these constituents during the time period selected for the study. However, verification of the initial dilution model provides confidence that the water quality standards are being met.

- *Other Constituents.* Other constituents were not considered in the formulation of the mixing zone. Data from the priority pollutant scans and bioassay tests indicate that acute and chronic mixing zones, if required, of small size and limited exposure time could be supported by the existing diffuser design.

SUMMARY AND RECOMMENDATIONS

The results and conclusions of the model verification study indicate that the model predictions used to design the diffuser, locate the outfall, and define the ZOM were accurate and appropriate. The water quality standards appear to be met throughout the harbor with the possible exception of some portion of the inner harbor. In the inner harbor, for some constituents, and for some periods of time, ASWQS may not be fully complied with. However, the JCO discharge can not be directly responsible for the noncompliance. The contribution of the JCO discharge to the water quality of the inner harbor can not be completely determined with the existing models and the available data.

To address the questions raised during the study CH2M HILL, recommends that the Model Verification Study be modified to include two further model studies (rather than the three future tasks indicated in the NPDES permits for the current permit period ending October 1997). This is recommended for a variety of reasons including:

- There is no further need to verify the initial and subsequent dilution models since no additional dye studies will be done under the present permit.

- There is only limited need to further verify the wastefield transport model (PT121) since it has been calibrated, verified with inner harbor discharge data during the Feasibility Study (CH2M HILL, 1991b), and verified with the outer harbor discharge data as described above. One addition verification with outer harbor data may be useful but any further study would be redundant and not add any useful information.

- The use of the wastefield transport model to further investigate BOD impacts is probably not warranted. Since the model was used to investigate extreme worst case conditions, substantial additional information can not be gained by additional model runs.

- The nearfield BOD impacts have not been addressed because of lack of data. It would be useful to address this question to a limited extent using the March 1995 water quality data collected by CH2M HILL (CH2M HILL, 1995) and any other information or data that may be collected.

- The ASWQS are being complied with except in the inner harbor. The question of cause and contribution from the JCO for observations in the inner harbor will arise. To answer these questions a model that can address variations in depth and nutrient algal dynamics will be required. CH2M HILL recommends that, using additional water quality data, a refined model setup for the Harbor using the WASP5 model be produced and calibrated. Some data is available from the March 1995 water quality data referenced above, and additional data may become available if USEPA and ASEPA approve the recommendations made in an earlier report (CH2M HILL, 1995) concerning the Receiving Water Quality Monitoring Program.

Based on the observations and rationale listed above CH2M HILL recommends the two additional modelling reports be structured as follows:

- Report No. 2 would present: [1] an analysis of nearfield DO impacts using a conservative approach and including the effects of NBOD as well as CBOD, and, [2] an additional verification exercise of the PT121 wastefield transport model using data recorded subsequent to the data used this report (No. 1). The report would be submitted by 31 December 1995, and would incorporate the March 1995 water quality data collected by CH2M HILL.

- Report No. 3 would present an analyses based on a WASP5 model configuration of the harbor. This will permit the incorporation of vertical structure in the nutrient transport, and allow the inclusion of chlorophyll-a predictions. The objective will be to determine the relative importance of various sources of nutrients following the relocation of the discharge and high strength waste segregation. The report would be submitted by 31 December 1996, and would incorporate any additional water quality data and the results of the Eutrophication Study.

These recommendations are consistent with recommendations made for changes in the Receiving Water Quality Monitoring Program to include more detail, including profiles and more sampling depths, at less frequent intervals. The recommendations above will also be consistent with the recommendations that will be made in the Eutrophication Study (Part H of the NPDES Permits). Lack of sufficient data led to the use of a modified PT121 application for the Eutrophication Study rather than WASP4. Although, the use of PT121 was an option in the study plan, it is recommended that a WASP5 model be done for the Harbor to replace the use of PT121 in the future. The Eutrophication Study report is in preparation at this time.

Section 6

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ADDENDUM

TO

JOINT CANNERY OUTFALL
MODEL PREDICTION VERIFICATION STUDY
Report No. 1

Response to USEPA Comments on the Study Plan

with

USEPA Approval of and Comments on the Study Plan

and

The Study Plan

MEMORANDUM

CH2M HILL

TO: File

COPIES: Joint Cannery Outfall Model Prediction Verification Study: Report No. 1 Addendum

FROM: Steve Costa/CH2M HILL

DATE: 22 December 1994

SUBJECT: Response to Comments on Model Prediction Verification Study Plan

PROJECT: OPE30702.MD

The purpose of this memorandum is to present our responses to comments by Walter Frick on the model prediction verification study plan. Dr. Frick's comments were presented in USEPA's letter approving the study plan dated 1 November 1993. Although USEPA found the study plan satisfactory, responses to Dr. Frick's comments were requested, in particular his comment regarding the UM model versus the UDKHDEN model. This memorandum, with USEPA's letter and the study plan attached, is being included in the addendum to the first report on the Model Prediction Verification Study to complete the record for the study plan.

Comment 1: Use of UM instead of UDKHDEN. We agree that the UM model could have had advantages for the initial feasibility study and subsequent mixing zone determination. If that model had been available at the time these studies were done we would have included it in our model selection evaluation, and may well have chosen it for application. We understand and agree that UM does have advantages of more easily extending results beyond the trapping level and more easily including the background concentrations in the necessary evaluations. However, as described in the feasibility studies and mixing zone applications we did, of course, extend the predictions beyond the trapping level and did account for background concentrations with the models employed.

We used a set of models (UDKHDEN, CDIFF, and PT121) and superimposed these models to achieve the required predictions (UM would replace UDKHDEN and CDIFF). The set of models we used provide the same degree of realism as would have been achieved by UM. The use of CDIFF is essentially the same approach as used in UM to extend the results beyond the trapping level. The inclusion of background concentrations was done using "desk top" calculations when superimposing the results of the various models.

Since the permit condition J explicitly states that the study is to "*...verify the models used in the determination of the mixing zones...*", it is our understanding that the models initially used are the ones to be verified in the study. This precludes the substitution of a different model (UM) for the model verification study. We recognize that the application of UM in the future may be desirable but will not fulfill the requirements of the permit as stated. Therefore, we have not used the UM model in the model verification study.

Comment No. 2: Field data quality. We agree that attention to the quality of field data is quite important and recognize the sensitivity of the initial dilution models to small variations in some environmental parameters. We believe our QA/QC approach to the field data is adequate and reasonable for the recovery of good data in Pago Pago Harbor. We note the concern with density data (temperature and salinity profiles) and note that we were not satisfied with the data for the first dye study as described in the report. We took additional steps to improve these data for the second dye study, including upgrading our instrument. Fortunately, the data for the first study were not compromised in that portion of the water column where the plume initial dilution was observed, and the poor data in the upper portion of the water column data did not compromise the model verification study (more description is found in the model verification study report).

Comment No. 3: Sensitivity Analyses. In general, sensitivity analyses were conducted on the models during the feasibility and mixing zone definition studies. It is our intention to do additional sensitivity analyses only if needed to assist in interpreting or providing confidence in the verification study. For example, additional runs of the initial dilution model for variations in effluent temperature and density are appropriate. In the case of effluent temperature, the actual effluent temperature at the discharge port cannot be easily measured and it is appropriate to examine the sensitivity of the results over the probable range of temperatures. Effluent density will vary with salinity as well as to temperature, and it is appropriate to examine the sensitivity of the results over a range of salinities to provide higher confidence in the study results. Sensitivity to other factors may also be appropriate for similar reasons (for example, plume width during subsequent dilution).

We do not intend to use the sensitivity analyses to "tune" the models to agree with field measurements. The objective is to see if the original predictions of the models, as initially used, agree with field measurements. In the case of the wastefield transport model (PT121), the original calibration was based on inner harbor discharge point data. The model predictions will be evaluated using data consistent with the new outer harbor discharge point. If the original model, as calibrated, does not agree well with the new monitoring data for total nitrogen and total phosphorus, the diffusion coefficients may be adjusted so that the model can be better used for future predictions. This is the only "tuning" anticipated for previously used models. (Note: the application of a model for BOD/DO predictions is a new effort and may require the definition of additional coefficients based on available data.)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

November 1, 1993

Steven L. Costa
Project Manager
CH2M Hill
P.O. Box 12681
Oakland, CA 94604-2681

Re: Review of the Draft Joint Cannery Outfall Model Prediction Verification Study Plan

Dear Steve:

We reviewed the draft cannery outfall model prediction study plan as required by the canneries' NPDES permits and find it satisfactory. The modeling program outlined in the plan appears to address important modeling concerns: data collection, reduction and analysis; modeling; validation; calibration; and verification. Walter Frick, an expert in hydrographic modeling at EPA's Environmental Research Laboratory in Newport Oregon, also reviewed the plan, and had the following comments:

- While he thought the UDHKDEN model will give sufficiently conservative estimates of initial dilution, with the imminent publication of "Dilution Models for Effluent Discharges" (Second Edition, EPA/600/R-93/139, July 1993), he recommended the use of UM over UDKHDEN. He felt that the results would be somewhat more realistic beyond the trapping level and, as an extra benefit, it makes provisions for including background concentrations.

- Regarding the quality assurance section, he found it largely satisfactory, but cautioned that some attention should be paid to the quality of the field data, particularly salinity and temperature stratification data. He also felt that sensitivity analyses, as described, were important but that tuning should be kept to a minimum.

We would appreciate your response to Dr. Frick's comment regarding the use of the UM model. Should you have any questions regarding the UM model, you can contact Dr. Frick at (503) 867-4029.

Sincerely,

Pat Young
for Norman L. Lovelace, Chief
Office of Pacific Island and Native American Programs (E-4)

cc: Jim Cox, Van Camp Seafood Company
Norman Wei, StarKist Seafood Company
Tony Tausaga, American Samoa EPA
Sheila Wiegman, American Samoa EPA

AGENCY REVIEW DRAFT

JOINT CANNERY OUTFALL
MODEL PREDICTION VERIFICATION
STUDY PLAN

for

StarKist Samoa, Inc.
and
VCS Samoa Packing Company

to comply with NPDES Permits

AS0000019
and
AS0000027

August 1993

prepared by

CH2M HILL

JOINT CANNERY OUTFALL MODEL PREDICTION VERIFICATION STUDY PLAN

INTRODUCTION

This study plan describes the rationale and approach of the model prediction verification study for the Joint Cannery Outfall (JCO) in Pago Pago Harbor, American Samoa. The purpose, background, and general approach to the study are presented first. Then the following section provides a detailed explanation of the approaches proposed for the various individual study tasks. Discussions of Quality Control/Quality Assurance and reporting format are then presented, followed by a list of pertinent references. A technical description of the wastefield transport model, a key element of the study, is attached to the study plan.

PURPOSE

The study addresses the verification of models used to determine the permitted zone of mixing (ZOM) for the JCO. The purpose of this study plan is to describe the proposed approaches for: [1] using field data to verify the previous analyses of the fate and transport of cannery effluent, and [2] developing an evaluation effects of the discharge on dissolved oxygen (DO) concentrations throughout Pago Pago harbor.

BACKGROUND

The JCO is a new outfall operated by StarKist Samoa, Inc. and VCS Samoa Packing Company. The outfall discharges treated wastewater from the canneries into outer Pago Pago Harbor. The JCO replaces two separate outfalls that previously discharged effluent into the inner harbor near the canneries. The canneries began discharging through the JCO in February of 1992. In addition, prior to initiating discharge through the new outfall, the canneries implemented high strength waste segregation in August 1991. The high strength waste is disposed of in a permitted ocean disposal site and does not influence the harbor.

The effects of high strength waste segregation and outfall discharge relocation on the water quality of the harbor were modeled by CH2M HILL (1991a). The size and location of the ZOM was based on environmental and engineering studies which included model predictions of the initial and subsequent dilution and the farfield transport processes (CH2M HILL, 1991a). Newly issued NPDES permits are based on the approved zone of mixing.

The NPDES permits require implementation of a receiving water quality monitoring program to determine compliance with water quality standards. The monitoring program includes analysis of water samples from 17 specified stations throughout the harbor. The objective of the monitoring program is to document water quality near the outfall discharge, near the zone of initial dilution (ZID), within the ZOM and at the ZOM boundaries, and at other locations throughout the harbor. Data collection for the monitoring program is conducted monthly by the American Samoa EPA. Monitoring reports documenting the water quality data are submitted to USEPA on a quarterly basis.

Two dye studies are also required as conditions of the permits to observe the fate and transport of the effluent plume. The first (non-tradewind season) of these dye studies was conducted on February 17, 1993. The second (tradewind season) is scheduled to be performed in September/October 1993.

The data collected from the water quality monitoring program and from the dye studies allow direct observation of the fate and transport of the discharged effluent. The NPDES permit requirements dictate that these data be used to verify the model predictions used in the earlier engineering studies for determining the ZOM and to evaluate the effects of BOD in the effluent on DO in the receiving water. This requirement is described in Part J of NPDES permit Numbers AS0000027 and AS0000019 as follows:

> *"Within three months after both dye studies have been completed, the permittee, cooperatively with {Star-Kist Samoa, Inc.; Samoa Packing Co.}, shall submit a study plan to USEPA and ASEPA that will discuss how the permittees will utilize the results from the monitoring data and from the dye studies to verify the models used in the determination of the mixing zones (the 30-second dilution zone, the ZID, and the ZOM). Also, the plan shall discuss how the permittee will examine the effects of BOD_5 in the effluent on Dissolved Oxygen (DO) in the receiving water, utilizing an appropriate model and one year's worth of ambient data. Upon*

> *approval of the study plan by USEPA and ASEPA, the permittee shall initiate the studies indicated and submit reports on a yearly basis. Reports shall summarize renewed predictions of dilution rates and the size, location, and movement of the plume based on the calibrated models".*

This study plan is being submitted to the U.S. Environmental Protection Agency (USEPA) and American Samoa Environmental Protection Agency (ASEPA) to comply with the permit conditions.

APPROACH

The study is divided into two primary tasks:

- **Model Verification.** The modeling procedures used to establish the ZOM will be evaluated based on data collected during the dye studies and the water quality monitoring program.

- **BOD Impacts.** The effects of BOD (measured BOD_5) in the effluent on DO in the receiving waters will be evaluated.

The general approach to each of the major tasks is described below. A more detailed description of the methods to be used is described in the following section on Study Methods.

Model Verification

The basic approach used in the previous engineering study to determine the required mixing zone dimensions was to: estimate the large-scale, long-term average ambient receiving water concentrations using a wastefield transport model, evaluate initial and subsequent (or secondary) dilution for a range of conditions, and, based on model predictions, determine the appropriate location for the discharge and the required size of the ZOM to comply with American Samoa Water Quality Standards (ASWQS). This approach will be evaluated by running the models for the conditions present during the dye studies and water quality monitoring, as appropriate, and comparing the model results with the observed field data. The three separate subtasks identified above include:

- **Wastefield Transport Model.** Observed long-term average receiving water concentrations, on a harbor wide scale, for total nitrogen (TN) and total phosphorus (TP) will be based on concentrations observed at each of the water quality monitoring sampling stations. Average loadings of TN and TP to the harbor from the discharge will be calculated for the same period of time. The wastefield transport model will be run using these average loadings and evaluated by comparing the model results to the observed water quality data.

- **Initial and Subsequent Dilution Models.** The initial and subsequent dilution modeling procedures used to establish the mixing zone boundaries will be evaluated based on the dye study results. Model input will include measured currents, temperature and salinity profiles, and effluent flows present during each dye study. The model results will be compared to the dilutions observed during the dye studies and to previous predictions. The formulation of the effluent limits for ammonia were based on predicted diffuser performance in terms of initial dilution rate and magnitude. The predictions used for this purpose will be specifically evaluated as a part of this subtask.

- **Zone of Mixing Location and Size.** The ZOM location and dimensions will be re-evaluated if significant discrepancies between predicted and observed TN and TP values occur. Discrepancies will be addressed by recalibration of each model to match the observed data and running the re-calibrated models for a range of conditions representative of the worst case conditions expected in the harbor.

BOD Impacts

BOD impacts on receiving water DO will be evaluated using the same wastefield transport model, or an equivalent model, used to calculate ambient TN and TP concentrations. The impacts will be addressed using the verified (and possibly recalibrated) model discussed above to calculate the potential impacts of cannery effluent on DO levels throughout the harbor. A BOD/DO routine in the model will be used to simulate effects of various BOD loadings from the canneries discharge.

SCHEDULE

Sufficient information was collected from the first dye study to allow the formulation of this study plan. Therefore, the study plan is being submitted prior to the second dye study to facilitate coordination with the eutrophication study, also required as a NPDES permit condition. Coordination of the two studies will benefit both, but particularly assist in doing the eutrophication study. The proposed schedule is to have the report for initial model study finished and delivered to USEPA and ASEPA by May 31, 1994. The first report for the modeling study will include recommendations for subsequent annual reports as required in the permit condition. This schedule is based on the assumptions that the second dye study is carried out near the end of September or beginning of October 1993, and the water quality monitoring data are available by the end of 1993.

STUDY METHODS

This section provides a more detailed description of the approach summarized above. The major features of the methods used will also be discussed. The approach is designed to maintain consistency with the previous studies done to determine the appropriate outfall location and the size of the ZOM. The same models will be used, but the input conditions may be changed to reflect the data collected during the dye studies and the water quality monitoring program. Additional technical details concerning the models and previous model results can be found in the "*Engineering and Environmental Feasibility Evaluation of Waste Disposal Alternatives*" (CH2M HILL, 1991a), the "*Site Specific Zone of Mixing Determination for the Joint Cannery Outfall Project: Pago Pago Harbor American Samoa*" (CH2M HILL, 1991c), and the "*Environmental Impact Assessment for Joint Cannery Outfall Project, Pago Pago Harbor, American Samoa*" (CH2M HILL, 1991d and e).

MODEL VERIFICATION

Numerical model predictions used as the basis for defining the ZOM for the JCO addressed both the long-term effects of the discharge on the TN and TP levels throughout the harbor and the dilution and dispersion associated with initial and subsequent mixing processes in the vicinity of the diffuser. The long-term processes determine the average levels of the effluent constituents in the ambient receiving water of the harbor. These levels must be known to calculate constituent concentrations resulting from the initial and subsequent dilution processes. The ambient water is the diluting water for the initial dilution process and for an enclosed bay, such as Pago Pago harbor, the ambient concentrations are affected by the effluent discharge levels.

Verification of the previous model predictions will involve verifying predictions of long-term ambient constituent levels compared with levels measured during the water quality monitoring program, verifying initial and subsequent dilution predictions based on dye study results, and re-evaluation of constituent concentrations, if necessary, based on recalibrated models. Brief descriptions of the models used are included in the discussions below and more detailed technical information is referenced. Application of the various models to verify previous predictions and comply with the NPDES permit conditions are described below.

Wastefield Transport Model: Ambient Concentrations

Previous predictions of ambient conditions in Pago Pago Harbor because of the operation of the JCO used a wastefield transport model (PT121). This model is described in more detail in Attachment A and in CH2M HILL, 1991a. The model, developed by CH2M HILL, was based on a model originally developed by HRI (1989) for a wasteload allocation study of Pago Pago Harbor. The results were presented as a series of contour plots of TN and TP concentrations for a range of discharge loadings and alternative outfall sitings.

Water quality, effluent chemistry, flow data and additional oceanographic data collected since the outfall became operational will be used as input to the wastefield transport model. Long-term average TN and TP loadings from the cannery discharges will be calculated based on effluent monitoring data collected by the canneries for a period of at least one year. Loadings from other point sources (e.g. the Utulei Sewage Treatment Plant), nonpoint sources, and open ocean background (a boundary condition) will be estimated from available data. PT121, using the same geometry as used in the previous study (CH2M HILL, 1991a), and as calibrated for the previous study, will be run using the long-term average loadings.

Results will be presented in the form of contour plots of TN and TP throughout the harbor. These predicted concentrations will be compared to long-term average TN and TP levels measured at water quality monitoring stations over the same period of time. For comparison with predicted data, maximum, minimum and long-term average ambient concentrations will be determined for each of the station locations from quarterly water quality monitoring reports.

The previous model was calibrated for a data set based on discharges in the inner harbor. Some differences between model predictions and measured concentrations of TN and TP are expected. We anticipate the previous model results to be conservative (i.e. overpredict concentrations throughout the harbor). If necessary, the model will be recalibrated for the new location based on the available data. The predictions of the wastefield transport model, recalibrated if necessary, will be used for the re-evaluation of mixing zone location and size and for the BOD/DO evaluation described below.

Initial and Subsequent Dilution Models

Initial and subsequent dilution characteristics of the outfall were previously analyzed using the USEPA models UDKHDEN (Muellenhoff et al., 1985) for initial dilution and CDIFF (Yearsley, 1987) for subsequent dilution processes. The models were used to evaluate the diffuser performance and plume behavior for a range of effluent flow conditions for typical ambient receiving water conditions. The mixing zone characteristics were based on the worst case conditions.

UDKHDEN is a fully three-dimensional model that considers variable profiles throughout the zone of flow establishment and uses a fourth-order integration routine along the centerline of the effluent plume to trace plume position and dilution over time during the rapid initial dilution processes. The model predicts dilution (in terms of mixing with ambient water) and the trapping level of the effluent plume.

CDIFF is a passive diffusion plume model that can be applied following the momentum and buoyancy driven initial dilution process. Diffusion is calculated in the lateral direction only as the plume is advected in the longitudinal direction by ambient currents. The model allows specification of one of three functional forms for the coefficient of lateral eddy diffusivity (as a function of characteristic plume dimension). The model assumes the plume is trapped with a constant vertical extent or fully mixed over the depth of the water column. A constant current is assumed and the model accounts for a solid shoreline boundary parallel to the direction of the current.

The initial and subsequent dilution models will be run based on the as-built diffuser configuration and environmental and flow conditions measured during the dye studies. Input for the initial dilution model, UDKHDEN, will include: diffuser configuration (port size, port depth, and number and spacing of ports), temperature and salinity profiles, current profiles, and effluent flow and density. Temperature and salinity profiles were taken during the dye studies. The profiles taken nearest the diffuser will be used as representative of the conditions during initial dilution. A range of ambient currents will be selected based on the currents measured over the course of the studies. Initial and subsequent dilution model procedures used in the previous study will be repeated for the conditions observed during the dye studies.

Results of the dilution models will be presented as plots or tables of centerline and flux average dilution versus distance from the diffuser. The centerline dilutions observed during the dye studies will be compared to the predicted values. The dilution models are not easily calibrated without changes to the model code. However, a correction factor can be developed that relates model prediction to observation. This is functionally a calibration curve, and serves the same purpose as model calibration for a particular set of conditions. If required, correction or "calibration" factors will be developed and applied to model results. Corrected results will be applied to the re-evaluation of the mixing zone characteristics and the BOD/DO evaluation as described below. In addition, the results will be used to evaluate the effluent limits for ammonia (which are based on a ZID that depends on diffuser initial dilution performance), the predicted trapping level, and the size of the physical ZID.

Evaluation of Mixing Zone

If the difference between the model predictions and field observations for all three model predictions (wastefield transport, initial dilution, and subsequent dilution) is small the dilution models will not be recalibrated and re-evaluation of ZOM size and location will not be required. If it is determined that the model predictions are conservative (i.e. underpredict dilutions or overpredict the TN and TP levels) a qualitative description of the differences will be presented and the models will be recalibrated (or calibration factors developed) for use in the BOD/DO evaluation described below. If there is a significant discrepancy between the model predictions and field observations such that the models overpredict dilutions and underpredict TN and TP concentrations, the models will be recalibrated to minimize the differences between predicted and observed results and the size and location of the mixing zone will be re-evaluated.

Calibration of the wastefield transport model, if necessary, will be accomplished by varying the value of the diffusivity coefficient (K), varying the decay term for the constituent of concern, or a combination of both. The diffusion and decay coefficients can be varied along the longitudinal axis of the harbor. The previous analysis assumed a zero decay and the calibration of the model was based solely on varying K. The model configuration used different values of K for the inner and outer harbor. The dilution models will be calibrated, if necessary, primarily by varying the coefficient of lateral diffusivity in CDIFF and developing calibration factors for UDKHDEN and CDIFF as described above.

BOD/DO EVALUATION

The effects of BOD loadings in the cannery effluent on DO throughout the harbor will be evaluated using PT121, recalibrated if necessary, as described above, or using EPA's water quality model WASP4 (Ambrose et al., 1988). PT121 has been modified to include a routine developed to simulate BOD and DO interactions. The model is formulated for depth averaged applications and is useful for looking at long-term or slowly varying effects averaged through the water column. However, the available information on water column constituents in general (HRI, 1989; CH2M HILL, 1991a) and on dissolved oxygen in particular (CH2M HILL, 1991b) indicates that the water column can best be described as a two or three layer system. This effect is relatively small for TN and TP but may be significant for DO. Therefore, PT121 may be modified, or run in appropriate configurations, to simulate a multilayer system or WASP4 will be used for this evaluation. The decision on which model to use will be based on a review of available data and the extent of modifications required for PT121.

The model will be run for two kinds of simulations: an average long-term simulation such as that done for TN and TP as discussed above and for a representative time history of BOD inputs from the cannery discharges representing a worst case scenario. BOD_5 loadings based on available effluent chemistry data and observed DO levels from available water quality monitoring data will be used to calibrate the model. The horizontal and vertical diffusivities, decay of BOD and utilization of DO, consumption of DO other than by BOD, and re-aeration coefficients will be adjusted to achieve calibration. Other point and nonpoint sources of BOD will be identified if possible, however this "background" will be generally included as an additional calibration coefficient representing some elevation above open ocean background (included as a boundary condition). The calibrated model will be verified using a separate data set.

The wastefield transport model (PT121 or WASP4) can not be used to evaluate DO impacts within or in the immediate vicinity of the effluent plume. Therefore, results from the initial and subsequent dilution models will be applied to evaluate the nearfield effects within the effluent plume. This procedure will use the results of the wastefield transport model to provide ambient receiving water values as in the case of TN and TP described above. Measurements of immediate dissolved oxygen demand (IDOD) of the combined effluent from both canneries will be made in the field during the second dye study. The measured value of IDOD will be used for evaluation of the effects of BOD in the plume as it mixes with receiving water.

QUALITY ASSURANCE AND QUALITY CONTROL

Quality assurance and quality control will be achieved through use of the accepted and proven models executed by staff familiar with those models. Specific QA/QC measures include: validation, calibration and verification of models with field data, addressing a range of potential conditions where appropriate, sensitivity analyses, and documentation and maintenance of input and output files generated during modeling activities. A significant portion of the modeling effort is directed at keeping a high level of confidence in the predictions of the models. The purpose and scope of this effort and a description of the techniques that will be used are described below. There is often confusion and misunderstanding about the technical terminology used in this process. To avoid confusion the functions described as validation, calibration, and verification are defined below.

The purpose of the QA/QC effort is to provide a high level of confidence that the models are providing physically realistic predictions. There are two efforts required: first, it is important that the model configuration developed for the harbor be calibrated and verified (tested against site specific data) and, second, it is just as important that the basic model code be based on sound physical assumptions (the underlying science and mathematical formulation are accurate reflections of reality).

Validation. The models employed in the study are mathematical representations of physical processes. The mathematical equations used are solved numerically (approximate solutions) using a digital computer. It is important that this process, which is considerably removed from the actual physical processes and behavior of the harbor, accurately simulate what happens in the harbor. The process of validation uses representative parameters for simplified system configurations to determine if the predictions reflect reality. The process of validation begins as the initial model computer code is written and continues as long as the model code is used. It is particularly important that any changes in model code be checked for validity. The final element of validation is a determination of how sensitive a model is to changes in input parameters. An extremely sensitive model probably does not provide results with a high confidence level. Sensitivity checks will be carried out for each of the models for potentially critical parameters.

Calibration. Most numerical models of the type used here contain coefficients (e.g. friction factors, diffusion coefficients) that are often study site specific. Although there are generally accepted values for these coefficients, the range observed in nature is high and the models can be somewhat sensitive to the values selected. The process of calibration uses measured values of forcing functions and responses to determine the appropriate coefficients for the model configuration at the study site. Typically a set of field data, say water level, will be measured and the appropriate coefficient, in this case friction factor, will be varied until the model results match the observed results for the observed forcing function and model geometry.

In the case of the initial dilution model and, to a lesser extent, the subsequent dilution model, it may be inappropriate to modify the original model code. These models are intended for general use by EPA and consistency is an important consideration. In this case it is more appropriate to develop a correction factor or calibration curve to be applied to the results of the model. This process is similar to the development of calibration curves routinely developed for instrument read-outs or data measurements.

Verification. It is possible to "force" a model to reproduce observed results by means of calibration. Successful calibration does not necessarily mean that the model is operating correctly under other conditions. Verification is a check that utilizes an observed data set independent from the one used for calibration. Typically the calibrated model is run under different environmental conditions, say loadings of TN from the discharges, and the response of the model, in this case TN concentrations at selected points in the harbor, is compared to observed concentrations at those points. Verification, combined with validation and sensitivity determination, provides a high level of confidence that the model is simulating the system under a range of conditions.

Model Code Modifications. Model code modifications may be required for a variety of reasons. No modifications are planned for the primary algorithms except for possible revisions to PT121 as described above. Some minor changes in program structure to increase ease of use will probably be done. All model code changes will be documented and tested.

DATA ANALYSIS AND PRESENTATION

A report documenting the results of all analyses will be presented to EPA and ASEPA. The report will include summaries of all input data, modeling procedures, model calibration and verification, and model results. All pertinent model results and output files (as appropriate) will be reproduced as an appendix to the report. Model results will be presented both in tabular form and graphically (i.e. contour plots) as appropriate. The report will include: an executive summary; an introduction describing the background, rationale, and general approach of the study; a description of the methods used including model formulation and input data; a description of the model results; an evaluation of the model validity for predicting dilution and plume characteristics; an evaluation of the ZOM characteristics; and an evaluation of BOD impacts.

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ATTACHMENT A

PT121 Model Description

PT121 is based on the HARBOR model used for the Wasteload Allocation Study (HRI, 1989). The wasteload allocation study should be referenced for more information on the basic physical principles and model approach.

PT121 is a quasi-two-dimensional (Q2D) completely stirred tank reactor (CSTR) model. The term Q2D refers to the following model attributes:

- It is a two-dimension horizonal approach that is depth-averaged. There is no variation of any variable with depth. However, the depth does vary throughout the harbor model. It is not a constant-depth model.

- The model is set up in a grid that is laterally symmetric about the longitudinal axis of the model. The longitudinal axis is transformed into a straight line.

- The model grid is set up in two levels. Square cells of constant dimension are used for the calculation of concentrations and transport in both horizontal directions. Rectangular "line cells" are composed of integral numbers of cells in a line perpendicular to the harbor axis. These line cells form the basis for calculating total flow rates in the longitudinal direction and the input of nonpoint source flows and pollutant loading.

- Lateral advective flows are symmetrical about the longitudinal axis, and there is no advection across the longitudinal axis. These flows are calculated on the basis of mass conservation. Longitudinal advective flows are equally divided between individual cells in a line cell, with the provision of no flow through a solid boundary.

- Flow rates are on the basis of changes in volume due to tidal elevation changes. The water surface is considered to change instantaneously throughout the system. Tides are input in tabular form. Thus, longitudinal flows are calculated on the basis of conservation of mass.

- Point source flows and loadings are added to individual cells. Nonpoint source flows and loadings are added to line cells and are equally distributed to cells within the line cell.

- Diffusion coefficients and decay rates can vary along the longitudinal axis of the system but are constant within a line cell. Diffusion is the same in both horizontal directions.

- Diffusive transport is calculated as a Fickian process based on eddy diffusivity. This transport is calculated on a cell-by-cell basis with no transport allowed through a solid boundary.

The term CSTR refers to the following model approach to calculating concentration:

- The total mass of a constituent is calculated from the concentration and cell volume for each cell.

- On the basis of tidal data, the volume of the cell is changed.

- Advective transport is allowed to carry mass to and from adjoining cells on the basis of the concentration, flow rate, length of the time step, and area between the cells. The area is based on the average depth of the two cells and cell width.

- Diffusive transport carries mass between cells on the basis of concentration gradient, area between adjoining cells, and the length of the time step.

- Point source loadings are introduced into appropriate cells. Point source flows are also introduced into individual cells. The mass of constituent and volume of water are based on loadings, flows, and length of the time step.

- Nonpoint source inputs are calculated the same way as point source inputs, but each cell in a line cell has equal inputs.

- The original mass in each cell is allowed to decay on the basis of the specified first order decay constant and the length of the time step.

- Each of the inputs and outputs of mass into each cell is added to the initial mass less the amount of decay, and a new concentration is calculated.

PT121 is run by supplying the required instructions and parameters by means of input files read by the program as it executes. The model is written and compiled in TurboBasic on an IBM-compatible computer operating under

MSDOS. The input is in four separate files. The job control file provides input for:

- Input/output file names
- Size of model grid (number of cells)
- Time step length
- Horizontal cell dimension
- Where to start reading from tide data file
- Number of days to do calculations
- Number of point sources considered
- Amount of tidal data to be read
- Input/output control parameters
- Cells where point source loadings are found
- Point source loadings and flows

The hydrodynamics file provides input for cross-sectional area, width, and nonpoint source flows as a function of distance along the harbor (for each line cell).

The tidal data file provides input for tidal elevation as a function of time in tabular format. The water quality/geometry data file provides input for the following parameters and variables:

- Initial concentration as a function of distance along the harbor, and boundary concentration at the open end of the harbor.

- Eddy diffusion coefficient as a function of distance along the harbor.

- Decay rate coefficient as a function of distance along the harbor.

- Nonpoint source loading as a function of distance along the harbor.

- Definition of the cells constituting the side boundaries of the system.

- Depth of each cell at the appropriate tidal elevation.

- Definition of the boundary condition for each of the boundary cells of the system.

The model results are provided in three optional output files as specified in the job control input file. These files are described below, and example output to a printer is shown. The files consist of a "mirror file" that primarily presents the input, a hydrodynamics file that provides results of the flow calculations, and a water quality output file that provides the results of the transport calculations.

The mirror file provides a listing and tabulations of the input values read and initially manipulated by the program. The primary function of this file is to provide documentation and allow the operation of the program to be checked. The file is generally used for validation runs and is switched off during production runs. The mirror file has the following parts:

- A title page that provides a description of the important program and model control parameters

- A summary of hydrodynamic and geometric data

- A tabulation of the tidal data used by the routine

- A tabulation of water quality inputs including initial concentrations, diffusivity and decay coefficients, and loadings

- A tabulation of cell depths that are input in feet and converted to meters

- A table of boundary conditions. The significance of the various boundary conditions can be determined by reference to the model code

The hydrodynamics file is also generally used for program validation and is switched off during production runs. This file contains a tabulation for each time step of the change in volume, flow rate, cross-sectional area, and velocity for each line cell or line cell boundary.

The water quality output file gives a description of the concentration at the end of each time step in each cell. The output interval for both the hydrodynamics and water quality output files can be specified if each time step is not desired.

APPENDIX I
UDKHDEN MODEL INPUT/OUTPUT

PROGRAM UDKHDEN

SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH AMBIENT CURRENTS AND VERTICAL GRADIENTS. AUG 1985

UNIVERSAL DATA FILE:
CASE I.D. dye study #1 baseline case (dye1base.inp)
DISCHARGE= 0.1097 CU-M/S DENSITY=1.00467 G/CM3 ** DIAMETER= 0.1286-M
** NUMBER OF PORTS= 4 ** SPACING= 15.24-M ** DEPTH = 53.65-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	1.02258	0.185
6.10	1.02258	0.185
12.19	1.02258	0.185
18.29	1.02258	0.185
24.38	1.02258	0.185
30.48	1.02258	0.185
33.53	1.02258	0.161
36.58	1.02263	0.114
42.67	1.02274	0.091
43.59	1.02275	0.084
44.20	1.02275	0.079
45.72	1.02275	0.067
48.77	1.02275	0.044
50.29	1.02275	0.032
50.90	1.02275	0.027
52.43	1.02283	0.015
53.65	1.02289	0.006

FROUDE NO= 13.95, PORT SPACING/PORT DIA= 118.46
STARTING LENGTH= 0.739

ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DUCL	DRHO	DCCL	TIME	DILUTION
0.00	0.00	0.00	45.00	15.00	0.13	1.000	1.000	1.000	0.00	1.00
0.50	0.50	0.20	45.13	17.21	0.35	1.000	0.988	0.989	0.35	1.96
1.18	1.19	0.57	45.95	25.41	1.15	0.314	0.292	0.294	1.36	6.69
1.78	1.83	1.11	47.24	38.01	1.91	0.201	0.161	0.164	3.34	12.19
2.27	2.38	1.82	49.40	49.07	2.64	0.159	0.101	0.106	6.03	19.17
2.66	2.86	2.64	52.96	56.25	3.43	0.135	0.065	0.073	9.26	28.50
2.97	3.30	3.51	58.17	59.95	4.31	0.117	0.046	0.052	12.98	41.07
3.21	3.75	4.41	64.54	60.91	5.26	0.102	0.034	0.038	17.18	57.73
3.40	4.22	5.31	70.87	59.58	6.25	0.089	0.026	0.029	21.86	79.06
3.56	4.74	6.18	76.12	56.59	7.21	0.077	0.020	0.023	27.00	105.16
3.68	5.32	7.02	79.99	52.66	8.11	0.067	0.017	0.019	32.61	135.64
3.78	5.97	7.82	82.67	48.46	8.94	0.057	0.014	0.016	38.70	169.82
3.92	7.42	9.26	85.76	40.80	10.40	0.039	0.011	0.012	52.38	245.80
4.01	9.05	10.51	87.30	34.71	11.67	0.023	0.008	0.010	68.31	328.32
4.08	10.79	11.60	88.13	29.35	12.87	0.010	0.004	0.009	86.94	412.52
4.13	12.63	12.53	88.58	24.30	13.98	-0.001	0.000	0.008	108.64	491.97

I.D.

PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

4.16	13.82	13.03	88.77	21.13	14.64	-0.008	-0.002	0.008	124.59	538.36
4.18	14.78	13.38	88.88	18.51	15.17	-0.014	-0.003	0.007	139.36	574.17

PLUMES MERGING

X	Y	Z	TH1	TH2	WIDTH	DUCL	DRHO	DCCL	TIME	DILUTION
4.20	15.77	13.68	89.02	15.17	15.73	-0.021	-0.004	0.007	156.87	607.04
4.22	16.77	13.92	89.12	12.04	16.30	-0.027	-0.005	0.007	178.25	635.19
4.23	17.78	14.11	89.19	9.07	16.83	-0.031	-0.006	0.007	204.38	658.64
4.24	18.80	14.24	89.24	6.18	17.28	-0.034	-0.007	0.007	235.79	677.31
4.26	19.83	14.33	89.27	3.34	17.60	-0.036	-0.007	0.007	271.87	691.04
4.27	20.85	14.36	89.29	0.56	17.76	-0.037	-0.007	0.007	310.28	699.84

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT
TRAPPING LEVEL= 41.03 METERS BELOW SURFACE, DILUTION= 499.22
ERROR IN INPUT DATA. PLEASE CHECK FILE

PROGRAM UDKHDEN
SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS. AUG 1985

UNIVERSAL DATA FILE:
CASE I.D. dye study #1 maximum flow case (dye1fmax.inp)
DISCHARGE= 0.1918 CU-M/S DENSITY=1.00467 G/CM3 ** DIAMETER= 0.1286-M
** NUMBER OF PORTS= 4 ** SPACING= 15.24-M ** DEPTH = 53.65-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	1.02258	0.185
6.10	1.02258	0.185
12.19	1.02258	0.185
18.29	1.02258	0.185
24.38	1.02258	0.185
30.48	1.02258	0.185
33.53	1.02258	0.161
36.58	1.02263	0.114
42.67	1.02274	0.091
43.59	1.02275	0.084
44.20	1.02275	0.079
45.72	1.02275	0.067
48.77	1.02275	0.044
50.29	1.02275	0.032
50.90	1.02275	0.027
52.43	1.02283	0.015
53.65	1.02289	0.006

FROUDE NO= 24.39, PORT SPACING/PORT DIA= 118.46
STARTING LENGTH= 0.743

ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DUCL	DRHO	DCCL	TIME	DILUTION
0.00	0.00	0.00	45.00	15.00	0.13	1.000	1.000	1.000	0.00	1.00
0.51	0.51	0.20	45.07	15.72	0.35	1.000	0.996	0.996	0.20	1.94
1.20	1.21	0.50	45.51	18.58	1.16	0.306	0.299	0.300	0.79	6.48
1.87	1.90	0.87	46.11	24.05	1.95	0.183	0.172	0.174	1.99	11.33
2.50	2.56	1.34	46.95	31.00	2.73	0.134	0.116	0.120	3.77	16.71
3.07	3.18	1.93	48.17	38.07	3.49	0.108	0.083	0.089	6.04	22.92
3.58	3.77	2.60	49.95	44.13	4.27	0.092	0.060	0.068	8.74	30.37
4.02	4.32	3.35	52.50	48.77	5.09	0.081	0.047	0.054	11.84	39.49
4.40	4.85	4.14	55.92	52.00	5.95	0.072	0.037	0.043	15.29	50.76
4.73	5.37	4.97	60.12	53.74	6.86	0.064	0.030	0.035	19.08	64.56
5.01	5.91	5.80	64.75	54.04	7.79	0.058	0.025	0.028	23.22	81.19
5.25	6.47	6.63	69.30	53.09	8.71	0.052	0.021	0.024	27.68	100.73
5.62	7.71	8.23	76.73	48.66	10.42	0.041	0.016	0.018	37.60	147.78
5.89	9.12	9.70	81.49	42.88	11.92	0.030	0.013	0.014	48.90	203.60
6.08	10.68	11.03	84.30	37.24	13.26	0.021	0.009	0.012	61.81	265.05
6.22	12.37	12.19	85.90	31.81	14.59	0.014	0.004	0.010	76.48	327.80

PLUMES MERGING

6.33	14.17	13.19	87.01	25.40	15.83	0.006	0.000	0.009	93.48	386.26

PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

X	Y	Z	TH1	TH2	WIDTH	DUCL	DRHO	DCCL	TIME	DILUTION
6.39	15.35	13.70	87.51	21.36	16.60	0.001	-0.001	0.009	105.99	416.25
6.43	16.31	14.05	87.79	18.55	17.20	-0.003	-0.003	0.009	117.23	436.99
6.46	17.30	14.35	88.00	15.91	17.79	-0.006	-0.004	0.008	129.70	455.65
6.50	18.29	14.61	88.17	13.37	18.35	-0.008	-0.005	0.008	143.52	472.21
6.53	19.30	14.83	88.29	10.88	18.88	-0.011	-0.005	0.008	158.75	486.58
6.56	20.31	15.00	88.38	8.41	19.34	-0.012	-0.006	0.008	175.40	498.66
6.59	21.33	15.13	88.45	5.95	19.72	-0.014	-0.006	0.008	193.32	508.34
6.61	22.36	15.21	88.50	3.50	20.00	-0.014	-0.006	0.007	212.22	515.58
6.64	23.38	15.25	88.52	1.06	20.17	-0.015	-0.006	0.007	231.68	520.46

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT
TRAPPING LEVEL= 40.34 METERS BELOW SURFACE, DILUTION= 393.00

PROGRAM UDKHDEN
SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS. AUG 1985

UNIVERSAL DATA FILE:
CASE I.D. dye study #1 minimum flow case (dye1fmin.inp)
DISCHARGE= 0.0768 CU-M/S DENSITY=1.00467 G/CM3 ** DIAMETER= 0.1286-M
** NUMBER OF PORTS= 4 ** SPACING= 15.24-M ** DEPTH = 53.65-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	1.02258	0.185
6.10	1.02258	0.185
12.19	1.02258	0.185
18.29	1.02258	0.185
24.38	1.02258	0.185
30.48	1.02258	0.185
33.53	1.02258	0.161
36.58	1.02263	0.114
42.67	1.02274	0.091
43.59	1.02275	0.084
44.20	1.02275	0.079
45.72	1.02275	0.067
48.77	1.02275	0.044
50.29	1.02275	0.032
50.90	1.02275	0.027
52.43	1.02283	0.015
53.65	1.02289	0.006

FROUDE NO= 9.77, PORT SPACING/PORT DIA= 118.46
STARTING LENGTH= 0.732

ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DUCL	DRHO	DCCL	TIME	DILUTION
0.00	0.00	0.00	45.00	15.00	0.13	1.000	1.000	1.000	0.00	1.00
0.50	0.50	0.22	45.19	19.45	0.36	0.999	0.975	0.976	0.50	1.99
1.14	1.16	0.67	46.47	34.15	1.14	0.331	0.282	0.283	1.90	6.97
1.65	1.71	1.36	48.79	50.51	1.85	0.232	0.146	0.149	4.44	13.44
2.02	2.16	2.21	53.07	60.19	2.61	0.191	0.084	0.090	7.69	22.65
2.28	2.55	3.13	59.71	64.23	3.48	0.161	0.052	0.058	11.52	35.93
2.48	2.95	4.05	67.62	64.43	4.47	0.137	0.035	0.040	15.97	54.57
2.62	3.39	4.97	74.72	61.83	5.48	0.117	0.026	0.029	21.01	79.50
2.74	3.89	5.86	79.83	57.44	6.46	0.100	0.020	0.022	26.64	110.83
2.82	4.48	6.70	83.13	52.34	7.36	0.084	0.016	0.018	32.84	147.82
2.89	5.14	7.49	85.19	47.35	8.17	0.069	0.013	0.015	39.64	189.33
2.94	5.86	8.22	86.49	42.88	8.92	0.056	0.011	0.013	47.04	234.20
3.02	7.46	9.52	87.93	35.82	10.24	0.033	0.009	0.010	63.80	330.28
3.07	9.18	10.64	88.64	30.59	11.40	0.013	0.006	0.008	83.54	431.48
3.10	10.99	11.61	89.03	25.79	12.49	-0.002	0.002	0.007	106.93	532.18

ZID.

PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

3.13	12.64	12.34	89.23	21.47	13.41	-0.015	-0.001	0.007	131.05	616.72

3.14	13.61	12.69	89.31	18.89	13.93	-0.023	-0.002	0.007	147.37	663.60
3.15	14.59	13.00	89.38	16.24	14.45	-0.031	-0.003	0.006	166.58	708.39
3.16	15.58	13.27	89.43	13.51	14.97	-0.040	-0.004	0.006	190.23	750.35

PLUMES MERGING

X	Y	Z	TH1	TH2	WIDTH	DUCL	DRHO	DCCL	TIME	DILUTION
3.17	16.59	13.48	89.48	10.53	15.48	-0.048	-0.006	0.006	221.33	788.31
3.18	17.61	13.64	89.52	7.41	16.00	-0.055	-0.006	0.006	265.49	819.26
3.19	18.63	13.75	89.55	4.35	16.41	-0.059	-0.007	0.006	328.49	842.80
3.19	19.66	13.80	89.57	1.35	16.64	-0.060	-0.007	0.006	407.44	858.77

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT
TRAPPING LEVEL= 41.44 METERS BELOW SURFACE, DILUTION= 600.79

PROGRAM UDKHDEN
SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS. AUG 1985

UNIVERSAL DATA FILE:
CASE I.D. dye study #1 80 degree effluent case (dye1_80F.inp)
DISCHARGE= 0.1097 CU-M/S DENSITY=1.00635 G/CM3 ** DIAMETER= 0.1286-M
** NUMBER OF PORTS= 4 ** SPACING= 15.24-M ** DEPTH = 53.65-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	1.02258	0.185
6.10	1.02258	0.185
12.19	1.02258	0.185
18.29	1.02258	0.185
24.38	1.02258	0.185
30.48	1.02258	0.185
33.53	1.02258	0.161
36.58	1.02263	0.114
42.67	1.02274	0.091
43.59	1.02275	0.084
44.20	1.02275	0.079
45.72	1.02275	0.067
48.77	1.02275	0.044
50.29	1.02275	0.032
50.90	1.02275	0.027
52.43	1.02283	0.015
53.65	1.02289	0.006

FROUDE NO= 14.66, PORT SPACING/PORT DIA= 118.46
STARTING LENGTH= 0.739

ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DUCL	DRHO	DCCL	TIME	DILUTION
0.00	0.00	0.00	45.00	15.00	0.13	1.000	1.000	1.000	0.00	1.00
0.50	0.51	0.20	45.13	17.00	0.35	1.000	0.989	0.990	0.35	1.96
1.18	1.19	0.56	45.95	24.50	1.15	0.312	0.293	0.294	1.36	6.68
1.79	1.84	1.08	47.20	36.36	1.92	0.198	0.161	0.165	3.36	12.13
2.30	2.41	1.76	49.29	47.23	2.66	0.155	0.101	0.107	6.12	18.98
2.71	2.90	2.57	52.71	54.55	3.45	0.131	0.066	0.074	9.44	28.08
3.03	3.37	3.43	57.75	58.46	4.32	0.112	0.046	0.053	13.29	40.29
3.29	3.83	4.31	63.99	59.63	5.27	0.098	0.034	0.039	17.64	56.46
3.49	4.31	5.19	70.30	58.45	6.25	0.085	0.026	0.030	22.48	77.14
3.65	4.85	6.06	75.62	55.56	7.20	0.074	0.021	0.024	27.82	102.41
3.78	5.44	6.89	79.57	51.72	8.09	0.063	0.017	0.020	33.64	131.88
3.89	6.10	7.67	82.34	47.59	8.91	0.054	0.015	0.017	39.96	164.85
4.04	7.58	9.09	85.55	40.09	10.35	0.036	0.011	0.013	54.20	237.95
4.14	9.22	10.33	87.16	34.22	11.60	0.021	0.009	0.011	70.82	317.18
4.21	10.97	11.41	88.03	29.13	12.77	0.008	0.005	0.009	90.29	398.55 I.D.
4.27	12.81	12.34	88.51	24.19	13.87	-0.002	0.001	0.008	112.99	475.85

PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

4.30	13.99	12.83	88.71	21.03	14.53	-0.010	-0.002	0.008	129.70	521.59
4.32	14.96	13.18	88.84	18.40	15.06	-0.016	-0.003	0.008	145.24	556.93

PLUMES MERGING

X	Y	Z	TH1	TH2	WIDTH	DUCL	DRHO	DCCL	TIME	DILUTION
4.33	15.95	13.48	88.97	15.24	15.62	-0.022	-0.005	0.008	163.76	589.89
4.35	16.95	13.72	89.08	12.04	16.20	-0.028	-0.006	0.008	186.78	618.09
4.37	17.96	13.91	89.15	9.02	16.74	-0.033	-0.007	0.007	215.64	641.58
4.38	18.98	14.04	89.21	6.08	17.20	-0.036	-0.007	0.007	251.31	660.24
4.40	20.00	14.13	89.24	3.19	17.52	-0.038	-0.007	0.007	293.18	673.90
4.41	21.03	14.16	89.26	0.36	17.68	-0.038	-0.008	0.007	337.89	682.61

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT
TRAPPING LEVEL= 41.19 METERS BELOW SURFACE, DILUTION= 486.73
ERROR IN INPUT DATA. PLEASE CHECK FILE

PROGRAM UDKHDEN
SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS. AUG 1985

UNIVERSAL DATA FILE:
CASE I.D. dye study #1 (dye1.inp)
DISCHARGE= 0.1097 CU-M/S DENSITY=1.00128 G/CM3 ** DIAMETER= 0.1286-M
** NUMBER OF PORTS= 4 ** SPACING= 15.24-M ** DEPTH = 53.65-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	1.02258	0.185
6.10	1.02258	0.185
12.19	1.02258	0.185
18.29	1.02258	0.185
24.38	1.02258	0.185
30.48	1.02258	0.185
33.53	1.02258	0.161
36.58	1.02263	0.114
42.67	1.02274	0.091
43.59	1.02275	0.084
44.20	1.02275	0.079
45.72	1.02275	0.067
48.77	1.02275	0.044
50.29	1.02275	0.032
50.90	1.02275	0.027
52.43	1.02283	0.015
53.65	1.02289	0.006

FROUDE NO= 12.79, PORT SPACING/PORT DIA= 118.46
STARTING LENGTH= 0.748

ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DUCL	DRHO	DCCL	TIME	DILUTION
0.00	0.00	0.00	90.00	15.00	0.13	1.000	1.000	1.000	0.00	1.00
0.00	0.72	0.21	90.00	17.65	0.35	0.999	0.986	0.986	0.36	1.97
0.00	1.68	0.59	90.00	26.89	1.11	0.327	0.301	0.302	1.34	6.54
0.00	2.53	1.15	90.00	40.03	1.79	0.217	0.168	0.171	3.19	11.79
0.00	3.25	1.89	90.00	50.72	2.45	0.175	0.106	0.111	5.65	18.49
0.00	3.85	2.73	90.00	57.27	3.16	0.150	0.069	0.076	8.56	27.47
0.00	4.38	3.61	90.00	60.46	3.98	0.131	0.049	0.054	11.88	39.56
0.00	4.88	4.51	90.00	61.19	4.88	0.114	0.036	0.039	15.62	55.59
0.00	5.38	5.41	90.00	59.99	5.83	0.100	0.027	0.030	19.79	76.18
0.00	5.92	6.29	90.00	57.38	6.79	0.088	0.021	0.023	24.38	101.60
0.00	6.50	7.14	90.00	53.86	7.71	0.077	0.017	0.019	29.39	131.71
0.00	7.13	7.95	90.00	49.96	8.57	0.066	0.014	0.016	34.82	165.97
0.00	8.56	9.43	90.00	42.46	10.09	0.047	0.011	0.012	46.98	243.77
0.00	10.15	10.73	90.00	36.16	11.42	0.030	0.008	0.010	61.06	329.90
0.00	11.87	11.86	90.00	30.57	12.68	0.018	0.004	0.008	77.28	418.55
0.00	13.69	12.83	90.00	25.47	13.83	0.006	0.001	0.007	95.96	503.03

PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

0.00	15.10	13.44	90.00	21.80	14.61	-0.003	-0.001	0.007	112.29	560.93
0.00	16.06	13.81	90.00	19.31	15.12	-0.009	-0.002	0.007	124.74	597.38

PLUMES MERGING

X	Y	Z	TH1	TH2	WIDTH	DUCL	DRHO	DCCL	TIME	DILUTION
0.00	17.04	14.12	90.00	16.27	15.64	-0.015	-0.003	0.007	138.95	631.58
0.00	18.04	14.38	90.00	13.20	16.18	-0.021	-0.004	0.007	155.59	661.22
0.00	19.05	14.59	90.00	10.32	16.69	-0.026	-0.005	0.006	175.02	686.37
0.00	20.06	14.75	90.00	7.55	17.14	-0.029	-0.006	0.006	197.47	706.93
0.00	21.09	14.86	90.00	4.84	17.49	-0.032	-0.006	0.006	222.74	722.78
0.00	22.11	14.93	90.00	2.17	17.72	-0.033	-0.006	0.006	250.04	733.77
0.00	23.14	14.94	90.00	-0.45	17.82	-0.033	-0.006	0.006	278.00	739.92

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT
TRAPPING LEVEL= 40.60 METERS BELOW SURFACE, DILUTION= 523.60

PROGRAM UDKHDEN
SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS. AUG 1985

UNIVERSAL DATA FILE:
CASE I.D. dye study #2 baseline case (dye2base.inp)
DISCHARGE= 0.1342 CU-M/S DENSITY=1.00467 G/CM3 ** DIAMETER= 0.1286-M
** NUMBER OF PORTS= 4 ** SPACING= 15.24-M ** DEPTH = 53.65-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	1.02221	0.223
3.05	1.02221	0.223
6.10	1.02221	0.223
9.14	1.02221	0.223
10.97	1.02231	0.223
12.19	1.02231	0.223
13.72	1.02232	0.223
15.24	1.02232	0.223
18.29	1.02232	0.223
21.34	1.02233	0.223
24.38	1.02233	0.223
27.43	1.02234	0.223
30.48	1.02234	0.223
33.53	1.02235	0.194
36.58	1.02235	0.166
39.62	1.02236	0.137
42.67	1.02236	0.109
45.72	1.02237	0.080
48.77	1.02237	0.052
51.82	1.02238	0.023
53.65	1.02238	0.023
55.00	1.02238	0.023

FROUDE NO= 17.31, PORT SPACING/PORT DIA= 118.46
STARTING LENGTH= 0.737

ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DUCL	DRHO	DCCL	TIME	DILUTION
0.00	0.00	0.00	45.00	15.00	0.13	1.000	1.000	1.000	0.00	1.00
0.50	0.50	0.20	45.36	16.36	0.35	1.000	0.993	0.993	0.29	1.96
1.18	1.21	0.53	47.19	21.53	1.19	0.297	0.285	0.285	1.13	7.02
1.79	1.90	0.97	49.21	30.69	2.03	0.180	0.158	0.158	2.87	12.94
2.33	2.54	1.57	51.44	40.60	2.86	0.138	0.103	0.103	5.37	20.01
2.77	3.12	2.30	54.08	48.80	3.64	0.117	0.073	0.073	8.42	28.55
3.13	3.65	3.11	57.94	54.07	4.46	0.103	0.054	0.054	11.89	39.64
3.41	4.15	3.96	63.05	56.47	5.35	0.090	0.041	0.041	15.75	54.22
3.65	4.67	4.81	68.70	56.36	6.28	0.079	0.031	0.032	20.01	72.88
3.83	5.22	5.66	73.92	54.27	7.20	0.069	0.025	0.026	24.69	95.83
3.98	5.83	6.48	78.09	50.93	8.08	0.060	0.021	0.021	29.78	122.76
4.10	6.49	7.26	81.15	47.05	8.88	0.050	0.017	0.018	35.32	153.05
4.28	7.98	8.67	84.81	39.61	10.31	0.033	0.013	0.014	47.85	220.40
4.40	9.63	9.89	86.67	33.68	11.56	0.018	0.011	0.012	62.66	293.20

403.14
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4.48	11.38	10.96	87.70	29.27	12.66	0.005	0.009	0.010	80.22	368.41
4.55	13.21	11.91	88.32	25.96	13.67	-0.006	0.008	0.009	101.15	444.83
4.59	15.08	12.77	88.73	23.16	14.67	-0.017	0.007	0.008	126.53	526.07

PLUMES MERGING

X	Y	Z	TH1	TH2	WIDTH	DUCL	DRHO	DCCL	TIME	DILUTION
4.63	16.99	13.53	89.08	19.72	15.72	-0.028	0.006	0.008	159.07	611.25
4.66	18.95	14.17	89.33	16.69	16.84	-0.037	0.005	0.007	205.41	690.34
4.68	20.93	14.72	89.48	14.81	17.89	-0.042	0.004	0.006	267.13	764.42
4.69	22.93	15.23	89.59	13.49	18.84	-0.046	0.004	0.006	340.48	835.17
4.71	24.93	15.69	89.66	12.46	19.72	-0.048	0.003	0.005	418.97	903.34
4.73	28.96	16.52	89.76	10.88	21.30	-0.051	0.002	0.004	579.36	1032.57
4.74	33.02	17.25	89.82	9.68	22.75	-0.052	0.002	0.003	723.43	1154.73
4.75	37.08	17.91	89.85	8.69	24.07	-0.053	0.001	0.003	846.99	1270.45
4.76	41.15	18.50	89.88	7.86	25.31	-0.053	0.001	0.003	955.13	1380.20
4.77	45.24	19.03	89.90	7.13	26.52	-0.054	0.001	0.002	1051.70	1484.35
4.78	49.32	19.52	89.91	6.47	27.63	-0.054	0.000	0.002	1139.61	1583.18
4.78	53.42	19.96	89.93	5.88	28.73	-0.054	0.000	0.002	1220.58	1676.84
4.79	57.51	20.37	89.93	5.34	29.75	-0.054	0.000	0.002	1296.38	1765.50
4.79	61.61	20.73	89.94	4.84	30.66	-0.054	0.000	0.002	1367.61	1849.36

PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

4.80	64.18	20.94	89.94	4.55	31.09	-0.054	0.000	0.001	1409.54	1899.36
4.80	65.20	21.02	89.95	4.44	31.24	-0.054	0.000	0.001	1425.64	1918.88
4.80	66.23	21.10	89.95	4.33	31.40	-0.053	0.000	0.001	1441.47	1938.11
4.80	67.26	21.18	89.95	4.22	31.55	-0.053	0.000	0.001	1457.03	1957.05
4.80	68.28	21.25	89.95	4.11	31.70	-0.053	0.000	0.001	1472.34	1975.70
4.80	69.31	21.33	89.95	4.01	31.85	-0.053	0.000	0.001	1487.41	1994.05
4.80	70.34	21.40	89.95	3.91	32.00	-0.053	0.000	0.001	1502.26	2012.12
4.80	71.36	21.47	89.95	3.81	34.23	-0.062	0.000	0.002	1519.40	2030.28
4.80	72.39	21.53	89.95	3.70	34.51	-0.062	0.000	0.002	1541.22	2048.74
4.80	73.42	21.60	89.95	3.59	34.74	-0.063	0.000	0.002	1563.17	2066.99
4.80	74.44	21.66	89.96	3.49	34.97	-0.063	0.000	0.002	1585.23	2084.98
4.81	75.47	21.72	89.96	3.38	35.18	-0.063	0.000	0.002	1607.38	2102.72
4.81	76.50	21.78	89.96	3.28	35.39	-0.064	0.000	0.002	1629.61	2120.20
4.81	77.53	21.84	89.96	3.18	35.60	-0.064	0.000	0.001	1651.89	2137.43
4.81	78.55	21.90	89.96	3.08	35.79	-0.064	0.000	0.001	1674.21	2154.39
4.81	79.58	21.95	89.96	2.98	35.98	-0.064	0.000	0.001	1696.55	2171.10
4.81	80.61	22.00	89.96	2.88	36.17	-0.065	0.000	0.001	1718.87	2187.54
4.81	81.64	22.06	89.96	2.79	36.34	-0.065	0.000	0.001	1741.17	2203.71
4.81	82.67	22.10	89.96	2.69	36.51	-0.065	0.000	0.001	1763.42	2219.62
4.81	83.69	22.15	89.96	2.59	36.67	-0.065	0.000	0.001	1785.59	2235.26
4.81	84.72	22.20	89.96	2.50	36.82	-0.065	0.000	0.001	1807.68	2250.63
4.81	85.75	22.24	89.96	2.41	36.97	-0.065	0.000	0.001	1829.66	2265.73
4.81	86.78	22.28	89.96	2.31	37.11	-0.065	0.000	0.001	1851.52	2280.55
4.81	87.81	22.33	89.96	2.22	37.24	-0.065	0.000	0.001	1873.24	2295.11
4.81	88.84	22.36	89.96	2.13	37.36	-0.065	0.000	0.001	1894.79	2309.39
4.81	89.86	22.40	89.96	2.04	37.48	-0.065	0.000	0.001	1916.18	2323.39
4.82	90.89	22.44	89.96	1.95	37.60	-0.065	0.000	0.001	1937.39	2337.13
4.82	91.92	22.47	89.97	1.86	37.70	-0.065	0.000	0.001	1958.41	2350.58
4.82	92.95	22.50	89.97	1.78	37.80	-0.065	0.000	0.001	1979.22	2363.76

4.82	93.98	22.54	89.97	1.69	37.90	-0.065	0.000	0.001	1999.83	2376.66
4.82	95.01	22.57	89.97	1.61	37.99	-0.065	0.000	0.001	2020.22	2389.29
4.82	96.04	22.59	89.97	1.52	38.07	-0.065	0.000	0.001	2040.39	2401.64
4.82	97.07	22.62	89.97	1.44	38.15	-0.065	0.000	0.001	2060.33	2413.72
4.82	98.09	22.65	89.97	1.36	38.23	-0.065	0.000	0.001	2080.04	2425.51
4.82	99.12	22.67	89.97	1.27	38.29	-0.064	0.000	0.001	2099.52	2437.04
4.82	100.15	22.69	89.97	1.19	38.36	-0.064	0.000	0.001	2118.77	2448.29
4.82	101.18	22.71	89.97	1.11	38.42	-0.064	0.000	0.001	2137.79	2459.27
4.82	102.21	22.73	89.97	1.04	38.48	-0.064	0.000	0.001	2156.57	2469.97

X	Y	Z	TH1	TH2	WIDTH	DUCL	DRHO	DCCL	TIME	DILUTION
4.82	103.24	22.75	89.97	0.96	38.53	-0.064	0.000	0.001	2175.11	2480.40
4.82	104.27	22.77	89.97	0.88	38.58	-0.063	0.000	0.001	2193.43	2490.57
4.82	105.30	22.78	89.97	0.80	38.62	-0.063	0.000	0.001	2211.52	2500.46
4.82	106.33	22.79	89.97	0.73	38.66	-0.063	0.000	0.001	2229.37	2510.08
4.82	107.36	22.81	89.97	0.65	38.70	-0.063	0.000	0.001	2247.00	2519.44
4.83	108.38	22.82	89.97	0.58	38.73	-0.062	0.000	0.001	2264.41	2528.53
4.83	109.41	22.83	89.97	0.51	38.76	-0.062	0.000	0.001	2281.60	2537.35
4.83	110.44	22.84	89.97	0.44	38.79	-0.062	0.000	0.001	2298.56	2545.91
4.83	111.47	22.84	89.97	0.36	38.81	-0.062	0.000	0.001	2315.32	2554.21
4.83	112.50	22.85	89.97	0.29	38.83	-0.061	0.000	0.001	2331.86	2562.26
4.83	113.53	22.85	89.97	0.22	38.85	-0.061	0.000	0.001	2348.19	2570.04
4.83	114.56	22.86	89.97	0.16	38.86	-0.061	0.000	0.001	2364.32	2577.57
4.83	115.59	22.86	89.97	0.09	38.88	-0.060	0.000	0.001	2380.25	2584.84
4.83	116.62	22.86	89.97	0.02	38.89	-0.060	0.000	0.001	2395.98	2591.88

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT
TRAPPING LEVEL= 32.78 METERS BELOW SURFACE, DILUTION=1881.07

PROGRAM UDKHDEN
SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS. AUG 1985

UNIVERSAL DATA FILE:
CASE I.D. dye study #2 maximum flow case (dye2fmax.inp)
DISCHARGE= 0.2101 CU-M/S DENSITY=1.00467 G/CM3 ** DIAMETER= 0.1286-M
** NUMBER OF PORTS= 4 ** SPACING= 15.24-M ** DEPTH = 53.65-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	1.02221	0.223
3.05	1.02221	0.223
6.10	1.02221	0.223
9.14	1.02221	0.223
10.97	1.02231	0.223
12.19	1.02231	0.223
13.72	1.02232	0.223
15.24	1.02232	0.223
18.29	1.02232	0.223
21.34	1.02233	0.223
24.38	1.02233	0.223
27.43	1.02234	0.223
30.48	1.02234	0.223
33.53	1.02235	0.194
36.58	1.02235	0.166
39.62	1.02236	0.137
42.67	1.02236	0.109
45.72	1.02237	0.080
48.77	1.02237	0.052
51.82	1.02238	0.023
53.65	1.02238	0.023
55.00	1.02238	0.023

FROUDE NO= 27.10, PORT SPACING/PORT DIA= 118.46
STARTING LENGTH= 0.741

ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DUCL	DRHO	DCCL	TIME	DILUTION
0.00	0.00	0.00	45.00	15.00	0.13	1.000	1.000	1.000	0.00	1.00
0.51	0.51	0.20	45.23	15.54	0.35	1.000	0.997	0.997	0.18	1.95
1.19	1.21	0.49	46.35	17.67	1.18	0.298	0.293	0.293	0.72	6.73
1.86	1.92	0.83	47.55	22.00	2.02	0.175	0.167	0.167	1.86	12.00
2.48	2.62	1.26	48.82	27.84	2.86	0.126	0.114	0.114	3.56	17.83
3.05	3.29	1.79	50.18	34.29	3.69	0.101	0.084	0.084	5.76	24.32
3.57	3.92	2.42	51.83	40.42	4.46	0.087	0.066	0.066	8.39	31.74
4.02	4.52	3.12	54.18	45.39	5.25	0.076	0.052	0.053	11.38	40.77
4.41	5.10	3.88	57.36	48.89	6.09	0.068	0.042	0.043	14.69	51.88
4.75	5.67	4.67	61.29	50.82	6.96	0.061	0.034	0.035	18.32	65.51
5.04	6.25	5.47	65.67	51.20	7.85	0.054	0.028	0.029	22.27	81.92
5.28	6.85	6.26	70.01	50.25	8.73	0.048	0.024	0.024	26.53	101.17
5.67	8.16	7.80	77.11	45.77	10.35	0.037	0.018	0.019	36.02	147.15

5.94	9.65	9.20	81.65	40.06	11.78	0.026	0.014	0.015	46.96	200.89
6.13	11.27	10.45	84.35	34.86	13.04	0.016	0.012	0.013	59.62	259.23
6.28	12.99	11.56	85.97	30.66	14.18	0.008	0.010	0.011	74.33	319.77
6.39	14.79	12.56	86.99	27.38	15.23	0.000	0.009	0.010	91.48	381.05 —— ID

PLUMES MERGING

X	Y	Z	TH1	TH2	WIDTH	DUCL	DRHO	DCCL	TIME	DILUTION
6.47	16.66	13.42	87.94	22.39	16.31	-0.008	0.008	0.009	112.43	439.14
6.53	18.58	14.15	88.49	19.38	17.39	-0.014	0.007	0.009	138.29	493.18
6.57	20.54	14.79	88.83	17.40	18.46	-0.019	0.006	0.008	168.85	544.87
6.61	22.51	15.38	89.07	15.96	19.47	-0.022	0.005	0.007	203.47	595.00
6.64	24.49	15.93	89.24	14.83	20.45	-0.024	0.004	0.006	241.15	643.92
6.68	28.49	16.92	89.46	13.08	22.25	-0.028	0.003	0.005	322.53	738.14
6.71	32.51	17.80	89.60	11.74	23.92	-0.030	0.002	0.004	405.39	828.79
6.74	36.55	18.60	89.69	10.65	25.50	-0.031	0.002	0.004	485.33	915.96
6.76	40.60	19.33	89.75	9.72	27.03	-0.032	0.001	0.003	561.36	999.79
6.77	44.66	19.99	89.80	8.91	28.48	-0.033	0.001	0.003	633.25	1080.39
6.79	48.73	20.61	89.83	8.20	29.91	-0.034	0.001	0.003	701.76	1157.89
6.80	52.81	21.17	89.85	7.57	31.09	-0.034	0.001	0.002	766.66	1232.43
6.81	56.89	21.69	89.87	6.98	32.04	-0.034	0.000	0.002	826.78	1303.90
6.82	60.98	22.17	89.89	6.49	35.50	-0.042	0.000	0.002	910.53	1374.95
6.82	65.07	22.62	89.90	6.03	37.28	-0.045	0.000	0.002	1011.77	1444.58

PROGRAM UDKHDEN

SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS. AUG 1985

UNIVERSAL DATA FILE:
CASE I.D. dye study #2 minimum flow case (dye2fmin.inp)
DISCHARGE= 0.0883 CU-M/S DENSITY=1.00467 G/CM3 ** DIAMETER= 0.1286-M
** NUMBER OF PORTS= 4 ** SPACING= 15.24-M ** DEPTH = 53.65-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	1.02221	0.223
3.05	1.02221	0.223
6.10	1.02221	0.223
9.14	1.02221	0.223
10.97	1.02231	0.223
12.19	1.02231	0.223
13.72	1.02232	0.223
15.24	1.02232	0.223
18.29	1.02232	0.223
21.34	1.02233	0.223
24.38	1.02233	0.223
27.43	1.02234	0.223
30.48	1.02234	0.223
33.53	1.02235	0.194
36.58	1.02235	0.166
39.62	1.02236	0.137
42.67	1.02236	0.109
45.72	1.02237	0.080
48.77	1.02237	0.052
51.82	1.02238	0.023
53.65	1.02238	0.023
55.00	1.02238	0.023

FROUDE NO= 11.39, PORT SPACING/PORT DIA= 118.46
STARTING LENGTH= 0.728

ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DUCL	DRHO	DCCL	TIME	DILUTION
0.00	0.00	0.00	45.00	15.00	0.13	1.000	1.000	1.000	0.00	1.00
0.49	0.50	0.21	45.56	18.14	0.35	1.000	0.983	0.983	0.43	1.99
1.14	1.19	0.61	48.51	29.05	1.20	0.304	0.271	0.271	1.70	7.49
1.67	1.82	1.22	51.94	43.62	2.03	0.200	0.141	0.141	4.18	14.64
2.06	2.36	2.00	55.87	54.35	2.85	0.165	0.086	0.086	7.45	24.01
2.35	2.83	2.86	61.22	59.91	3.67	0.143	0.058	0.058	11.25	36.65
2.57	3.29	3.76	67.99	61.12	4.60	0.124	0.040	0.041	15.52	54.37
2.73	3.77	4.66	74.50	59.08	5.57	0.106	0.030	0.030	20.31	78.03
2.86	4.31	5.52	79.49	54.94	6.50	0.090	0.023	0.023	25.63	107.73
2.95	4.93	6.34	82.80	49.95	7.36	0.075	0.018	0.019	31.50	142.63
3.03	5.62	7.09	84.92	45.02	8.14	0.060	0.015	0.016	37.96	181.52
3.08	6.38	7.79	86.27	40.62	8.86	0.047	0.013	0.014	45.04	223.23
3.17	8.02	9.03	87.77	33.74	10.12	0.024	0.010	0.011	61.34	311.44
3.22	9.78	10.10	88.52	28.91	11.22	0.004	0.008	0.009	80.99	403.08

426.24
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3.26	11.61	11.03	88.95	25.36	12.23	-0.013	0.007	0.008	104.90	497.27
3.29	13.49	11.87	89.23	22.40	13.23	-0.028	0.006	0.007	134.69	599.03
3.31	15.41	12.61	89.41	19.94	14.23	-0.042	0.005	0.007	173.46	707.99
3.33	17.36	13.27	89.54	17.90	15.23	-0.056	0.005	0.006	228.39	823.56

PLUMES MERGING

X	Y	Z	TH1	TH2	WIDTH	DUCL	DRHO	DCCL	TIME	DILUTION
3.34	19.33	13.85	89.67	14.91	16.39	-0.071	0.004	0.006	338.16	936.45
3.35	21.33	14.35	89.75	13.06	17.44	-0.079	0.003	0.005	636.23	1040.06
3.36	23.34	14.79	89.80	11.78	18.33	-0.082	0.003	0.005	1241.16	1137.70
3.37	25.36	15.19	89.83	10.80	19.10	-0.083	0.002	0.004	1727.62	1230.72
3.38	29.42	15.91	89.88	9.29	20.46	-0.085	0.002	0.003	2395.00	1404.40
3.39	33.48	16.53	89.91	8.15	21.69	-0.085	0.001	0.003	2714.23	1565.73
3.39	37.56	17.08	89.92	7.22	22.83	-0.084	0.001	0.002	2924.70	1716.46
3.40	41.65	17.57	89.94	6.43	23.87	-0.084	0.000	0.002	3084.06	1857.53
3.40	45.75	18.00	89.95	5.74	24.85	-0.083	0.000	0.002	3214.98	1989.60
3.41	49.84	18.39	89.95	5.13	25.75	-0.082	0.000	0.002	3327.42	2113.18

PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

3.41	53.95	18.74	89.96	4.57	26.62	-0.082	0.000	0.002	3427.77	2228.76
3.41	54.97	18.82	89.96	4.44	26.85	-0.081	0.000	0.001	3451.10	2256.51
3.41	56.00	18.90	89.96	4.31	27.05	-0.081	0.000	0.001	3473.86	2283.80
3.41	57.03	18.98	89.96	4.18	27.24	-0.081	0.000	0.001	3496.11	2310.61
3.41	58.05	19.05	89.96	4.05	27.42	-0.081	0.000	0.001	3517.87	2336.93
3.41	59.08	19.12	89.96	3.93	27.60	-0.081	0.000	0.001	3539.18	2362.77
3.41	60.11	19.19	89.96	3.81	27.79	-0.080	0.000	0.001	3560.06	2388.14
3.41	61.13	19.26	89.97	3.69	27.98	-0.080	0.000	0.001	3580.58	2413.04
3.41	62.16	19.32	89.97	3.57	28.16	-0.080	0.000	0.001	3600.77	2437.48
3.41	63.19	19.39	89.97	3.46	28.35	-0.080	0.000	0.001	3620.64	2461.46
3.42	64.21	19.45	89.97	3.34	28.52	-0.080	0.000	0.001	3640.21	2484.98
3.42	65.24	19.51	89.97	3.23	28.69	-0.080	0.000	0.001	3659.47	2508.04
3.42	66.27	19.56	89.97	3.12	28.85	-0.080	0.000	0.001	3678.44	2530.64
3.42	67.30	19.62	89.97	3.01	29.01	-0.079	0.000	0.001	3697.12	2552.79
3.42	68.32	19.67	89.97	2.90	29.17	-0.079	0.000	0.001	3715.53	2574.48
3.42	69.35	19.72	89.97	2.79	29.32	-0.079	0.000	0.001	3733.68	2595.72
3.42	70.38	19.77	89.97	2.69	29.46	-0.079	0.000	0.001	3751.57	2616.51
3.42	71.41	19.82	89.97	2.58	29.60	-0.079	0.000	0.001	3769.21	2636.84
3.42	72.44	19.86	89.97	2.48	29.74	-0.078	0.000	0.001	3786.61	2656.73
3.42	73.47	19.91	89.97	2.37	29.87	-0.078	0.000	0.001	3803.78	2676.17
3.42	74.49	19.95	89.97	2.27	29.99	-0.078	0.000	0.001	3820.72	2695.16
3.42	75.52	19.99	89.97	2.17	30.11	-0.078	0.000	0.001	3837.45	2713.71
3.42	76.55	20.03	89.97	2.07	30.23	-0.077	0.000	0.001	3853.96	2731.81
3.42	77.58	20.06	89.97	1.98	30.35	-0.077	0.000	0.001	3870.28	2749.47
3.42	78.61	20.10	89.97	1.88	30.45	-0.077	0.000	0.001	3886.40	2766.70
3.42	79.64	20.13	89.97	1.78	30.55	-0.077	0.000	0.001	3902.32	2783.48
3.42	80.67	20.16	89.97	1.69	30.63	-0.076	0.000	0.001	3918.03	2799.82
3.42	81.69	20.19	89.97	1.60	30.71	-0.076	0.000	0.001	3933.55	2815.73
3.42	82.72	20.22	89.98	1.50	30.79	-0.076	0.000	0.001	3948.87	2831.21
3.42	83.75	20.25	89.98	1.41	30.86	-0.075	0.000	0.001	3964.02	2846.25
3.43	84.78	20.27	89.98	1.32	30.93	-0.075	0.000	0.001	3978.99	2860.88
3.43	85.81	20.29	89.98	1.24	31.00	-0.075	0.000	0.001	3993.80	2875.09

3.43	86.84	20.32	89.98	1.15	31.07	-0.074	0.000	0.001	4008.44	2888.88
3.43	87.87	20.34	89.98	1.06	31.14	-0.074	0.000	0.001	4022.93	2902.27
3.43	88.90	20.35	89.98	0.98	31.20	-0.074	0.000	0.001	4037.28	2915.24
3.43	89.93	20.37	89.98	0.90	31.26	-0.073	0.000	0.001	4051.47	2927.81
3.43	90.95	20.39	89.98	0.81	31.32	-0.073	0.000	0.001	4065.53	2939.98
3.43	91.98	20.40	89.98	0.73	31.37	-0.073	0.000	0.001	4079.46	2951.76
3.43	93.01	20.41	89.98	0.65	31.42	-0.072	0.000	0.001	4093.25	2963.14
3.43	94.04	20.42	89.98	0.57	31.47	-0.072	0.000	0.001	4106.93	2974.13
3.43	95.07	20.43	89.98	0.49	31.52	-0.072	0.000	0.001	4120.48	2984.73
3.43	96.10	20.44	89.98	0.42	31.57	-0.071	0.000	0.001	4133.91	2994.95

X	Y	Z	TH1	TH2	WIDTH	DUCL	DRHO	DCCL	TIME	DILUTION
3.43	97.13	20.45	89.98	0.34	31.61	-0.071	0.000	0.001	4147.23	3004.79
3.43	98.16	20.45	89.98	0.26	31.65	-0.071	0.000	0.001	4160.44	3014.26
3.43	99.19	20.46	89.98	0.19	31.69	-0.070	0.000	0.001	4173.55	3023.35
3.43	100.22	20.46	89.98	0.11	31.72	-0.070	0.000	0.001	4186.55	3032.07
3.43	101.25	20.46	89.98	0.04	31.76	-0.070	0.000	0.001	4199.45	3040.43

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT
TRAPPING LEVEL= 34.98 METERS BELOW SURFACE, DILUTION=2204.81

PROGRAM UDKHDEN
SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS. AUG 1985

UNIVERSAL DATA FILE:
CASE I.D. dye study #2 80 degree effluent case (dye2_80F.inp)
DISCHARGE= 0.1342 CU-M/S DENSITY=1.00635 G/CM3 ** DIAMETER= 0.1286-M
** NUMBER OF PORTS= 4 ** SPACING= 15.24-M ** DEPTH = 53.65-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	1.02221	0.223
3.05	1.02221	0.223
6.10	1.02221	0.223
9.14	1.02221	0.223
10.97	1.02231	0.223
12.19	1.02231	0.223
13.72	1.02232	0.223
15.24	1.02232	0.223
18.29	1.02232	0.223
21.34	1.02233	0.223
24.38	1.02233	0.223
27.43	1.02234	0.223
30.48	1.02234	0.223
33.53	1.02235	0.194
36.58	1.02235	0.166
39.62	1.02236	0.137
42.67	1.02236	0.109
45.72	1.02237	0.080
48.77	1.02237	0.052
51.82	1.02238	0.023
53.65	1.02238	0.023
55.00	1.02238	0.023

FROUDE NO= 18.21, PORT SPACING/PORT DIA= 118.46
STARTING LENGTH= 0.737

ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DUCL	DRHO	DCCL	TIME	DILUTION
0.00	0.00	0.00	45.00	15.00	0.13	1.000	1.000	1.000	0.00	1.00
0.50	0.50	0.20	45.36	16.22	0.35	1.000	0.994	0.994	0.29	1.96
1.18	1.21	0.52	47.19	20.88	1.19	0.297	0.286	0.286	1.13	7.01
1.80	1.91	0.95	49.19	29.32	2.04	0.178	0.158	0.158	2.89	12.91
2.34	2.56	1.53	51.41	38.75	2.87	0.135	0.104	0.104	5.42	19.89
2.80	3.16	2.23	53.96	46.89	3.67	0.114	0.074	0.074	8.54	28.25
3.18	3.71	3.01	57.65	52.34	4.48	0.099	0.055	0.055	12.12	39.02
3.48	4.23	3.85	62.57	54.98	5.36	0.087	0.042	0.042	16.11	53.13
3.72	4.76	4.69	68.12	55.10	6.28	0.077	0.032	0.033	20.51	71.15
3.92	5.33	5.53	73.34	53.21	7.19	0.067	0.026	0.026	25.34	93.29
4.08	5.95	6.33	77.58	50.02	8.05	0.057	0.021	0.022	30.61	119.26
4.21	6.62	7.10	80.72	46.25	8.85	0.048	0.018	0.019	36.34	148.44
4.40	8.13	8.49	84.52	38.99	10.26	0.031	0.014	0.015	49.34	213.23
4.52	9.79	9.70	86.47	33.17	11.49	0.016	0.011	0.012	64.77	283.14

375.33
ID

4.61	11.55	10.76	87.56	28.84	12.58	0.003	0.009	0.011	83.16	355.26
4.68	13.38	11.70	88.21	25.55	13.59	-0.008	0.008	0.010	105.29	428.86
4.73	15.26	12.54	88.65	22.76	14.59	-0.018	0.007	0.009	132.50	507.62

PLUMES MERGING

X	Y	Z	TH1	TH2	WIDTH	DUCL	DRHO	DCCL	TIME	DILUTION
4.77	17.17	13.29	89.00	19.63	15.65	-0.029	0.006	0.008	167.86	590.87
4.80	19.13	13.92	89.28	16.49	16.79	-0.038	0.005	0.007	220.72	668.56
4.82	21.12	14.47	89.45	14.58	17.85	-0.044	0.005	0.007	294.86	741.08
4.84	23.11	14.96	89.56	13.24	18.81	-0.047	0.004	0.006	386.48	810.16
4.85	25.12	15.42	89.64	12.20	19.69	-0.049	0.003	0.005	485.06	876.58
4.87	29.16	16.23	89.74	10.61	21.24	-0.052	0.002	0.004	685.11	1002.10
4.89	33.21	16.94	89.80	9.40	22.66	-0.053	0.002	0.004	856.75	1120.31
4.90	37.28	17.58	89.84	8.41	23.96	-0.054	0.001	0.003	999.69	1232.02
4.91	41.36	18.15	89.87	7.57	25.17	-0.054	0.001	0.003	1121.18	1337.60
4.92	45.44	18.66	89.89	6.83	26.34	-0.054	0.001	0.002	1227.50	1437.44
4.93	49.53	19.13	89.91	6.18	27.41	-0.054	0.000	0.002	1323.25	1531.84
4.93	53.63	19.55	89.92	5.58	28.46	-0.054	0.000	0.002	1410.44	1620.97
4.94	57.72	19.93	89.93	5.03	29.44	-0.054	0.000	0.002	1491.50	1705.00

PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

4.94	60.29	20.15	89.93	4.70	30.04	-0.054	0.000	0.002	1539.28	1754.96
4.94	61.31	20.23	89.93	4.58	30.26	-0.054	0.000	0.002	1557.69	1774.45
4.95	62.34	20.32	89.94	4.45	30.47	-0.054	0.000	0.002	1575.82	1793.63
4.95	63.37	20.39	89.94	4.33	30.64	-0.054	0.000	0.002	1593.63	1812.50
4.95	64.39	20.47	89.94	4.22	30.79	-0.054	0.000	0.002	1611.10	1831.05
4.95	65.42	20.55	89.94	4.10	30.94	-0.053	0.000	0.002	1628.23	1849.29
4.95	66.45	20.62	89.94	3.99	31.09	-0.053	0.000	0.002	1645.07	1867.22
4.95	67.47	20.69	89.94	3.88	31.23	-0.053	0.000	0.002	1661.60	1884.84
4.95	68.50	20.76	89.94	3.77	31.37	-0.053	0.000	0.001	1677.86	1902.16
4.95	69.53	20.82	89.95	3.66	31.51	-0.053	0.000	0.001	1693.86	1919.18
4.95	70.55	20.89	89.95	3.56	31.64	-0.053	0.000	0.001	1709.60	1935.91
4.96	71.58	20.95	89.95	3.45	31.77	-0.053	0.000	0.001	1725.11	1952.34
4.96	72.61	21.01	89.95	3.35	31.90	-0.052	0.000	0.001	1740.39	1968.48
4.96	73.64	21.07	89.95	3.25	32.03	-0.052	0.000	0.001	1755.46	1984.33
4.96	74.66	21.13	89.95	3.15	34.30	-0.061	0.000	0.002	1772.92	2000.35
4.96	75.69	21.19	89.95	3.04	34.52	-0.061	0.000	0.002	1795.18	2016.58
4.96	76.72	21.24	89.95	2.93	34.70	-0.062	0.000	0.002	1817.46	2032.56
4.96	77.75	21.29	89.95	2.83	34.88	-0.062	0.000	0.002	1839.73	2048.27
4.96	78.78	21.34	89.95	2.72	35.05	-0.062	0.000	0.002	1861.97	2063.69
4.96	79.80	21.39	89.95	2.62	35.22	-0.062	0.000	0.002	1884.17	2078.84
4.96	80.83	21.43	89.95	2.52	35.37	-0.062	0.000	0.002	1906.29	2093.71
4.96	81.86	21.48	89.96	2.42	35.52	-0.062	0.000	0.002	1928.32	2108.29
4.96	82.89	21.52	89.96	2.32	35.67	-0.062	0.000	0.001	1950.24	2122.59
4.97	83.92	21.56	89.96	2.22	35.80	-0.062	0.000	0.001	1972.03	2136.61
4.97	84.94	21.60	89.96	2.12	35.93	-0.062	0.000	0.001	1993.68	2150.34
4.97	85.97	21.64	89.96	2.02	36.05	-0.062	0.000	0.001	2015.17	2163.78
4.97	87.00	21.67	89.96	1.93	36.16	-0.062	0.000	0.001	2036.48	2176.95
4.97	88.03	21.71	89.96	1.83	36.27	-0.062	0.000	0.001	2057.61	2189.82
4.97	89.06	21.74	89.96	1.74	36.37	-0.062	0.000	0.001	2078.55	2202.41
4.97	90.09	21.77	89.96	1.65	36.46	-0.062	0.000	0.001	2099.28	2214.72

4.97	91.12	21.80	89.96	1.56	36.55	-0.062	0.000	0.001	2119.79	2226.74
4.97	92.15	21.83	89.96	1.47	36.64	-0.062	0.000	0.001	2140.09	2238.47
4.97	93.17	21.85	89.96	1.38	36.72	-0.062	0.000	0.001	2160.16	2249.92
4.97	94.20	21.88	89.96	1.29	36.79	-0.062	0.000	0.001	2180.00	2261.09
4.97	95.23	21.90	89.96	1.20	36.86	-0.062	0.000	0.001	2199.61	2271.97
4.97	96.26	21.92	89.96	1.12	36.92	-0.061	0.000	0.001	2218.99	2282.58
4.97	97.29	21.94	89.96	1.03	36.98	-0.061	0.000	0.001	2238.13	2292.90
4.98	98.32	21.96	89.96	0.95	37.03	-0.061	0.000	0.001	2257.03	2302.93
4.98	99.35	21.97	89.96	0.87	37.08	-0.061	0.000	0.001	2275.70	2312.69

X	Y	Z	TH1	TH2	WIDTH	DUCL	DRHO	DCCL	TIME	DILUTION
4.98	100.38	21.99	89.96	0.79	37.12	-0.061	0.000	0.001	2294.13	2322.18
4.98	101.41	22.00	89.96	0.71	37.17	-0.060	0.000	0.001	2312.33	2331.38
4.98	102.44	22.01	89.96	0.63	37.20	-0.060	0.000	0.001	2330.29	2340.31
4.98	103.47	22.02	89.96	0.55	37.24	-0.060	0.000	0.001	2348.03	2348.97
4.98	104.49	22.03	89.96	0.47	37.27	-0.060	0.000	0.001	2365.54	2357.35
4.98	105.52	22.04	89.96	0.39	37.29	-0.059	0.000	0.001	2382.82	2365.46
4.98	106.55	22.05	89.96	0.32	37.32	-0.059	0.000	0.001	2399.88	2373.31
4.98	107.58	22.05	89.96	0.24	37.34	-0.059	0.000	0.001	2416.72	2380.89
4.98	108.61	22.05	89.96	0.17	37.35	-0.059	0.000	0.001	2433.35	2388.20
4.98	109.64	22.06	89.96	0.09	37.37	-0.058	0.000	0.001	2449.77	2395.26
4.98	110.67	22.06	89.96	0.02	37.38	-0.058	0.000	0.001	2465.97	2402.07

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT
TRAPPING LEVEL= 33.59 METERS BELOW SURFACE, DILUTION=1732.70

PROGRAM UDKHDEN
SOLUTION TO MULTIPLE BUOYANT DISCHARGE PROBLEM WITH
AMBIENT CURRENTS AND VERTICAL GRADIENTS. AUG 1985

UNIVERSAL DATA FILE:
CASE I.D. dye study #2 (dye2.inp)
DISCHARGE= 0.1342 CU-M/S DENSITY=1.00013 G/CM3 ** DIAMETER= 0.1286-M
** NUMBER OF PORTS= 4 ** SPACING= 15.24-M ** DEPTH = 53.65-M

AMBIENT STRATIFICATION PROFILE

DEPTH (M)	DENSITY (G/CM3)	VELOCITY (M/S)
0.00	1.02221	0.223
3.05	1.02221	0.223
6.10	1.02221	0.223
9.14	1.02221	0.223
10.97	1.02231	0.223
12.19	1.02231	0.223
13.72	1.02232	0.223
15.24	1.02232	0.223
18.29	1.02232	0.223
21.34	1.02233	0.223
24.38	1.02233	0.223
27.43	1.02234	0.223
30.48	1.02234	0.223
33.53	1.02235	0.194
36.58	1.02235	0.166
39.62	1.02236	0.137
42.67	1.02236	0.109
45.72	1.02237	0.080
48.77	1.02237	0.052
51.82	1.02238	0.023
53.65	1.02238	0.023
55.00	1.02238	0.023

FROUDE NO= 15.41, PORT SPACING/PORT DIA= 118.46
STARTING LENGTH= 0.763

ALL LENGTHS ARE IN METERS-TIME IN SEC. FIRST LINE ARE INITIAL CONDITIONS.

X	Y	Z	TH1	TH2	WIDTH	DUCL	DRHO	DCCL	TIME	DILUTION
0.00	0.00	0.00	90.00	15.00	0.13	1.000	1.000	1.000	0.00	1.00
0.00	0.74	0.21	90.00	16.76	0.35	1.000	0.991	0.991	0.30	1.98
0.00	1.71	0.55	90.00	22.72	1.10	0.322	0.305	0.305	1.10	6.62
0.00	2.62	1.02	90.00	32.49	1.82	0.204	0.173	0.173	2.67	11.92
0.00	3.43	1.65	90.00	42.42	2.54	0.159	0.113	0.113	4.85	18.32
0.00	4.14	2.40	90.00	50.27	3.23	0.136	0.080	0.080	7.48	26.26
0.00	4.76	3.22	90.00	55.11	3.97	0.119	0.058	0.059	10.46	36.70
0.00	5.33	4.07	90.00	57.27	4.80	0.105	0.044	0.044	13.79	50.46
0.00	5.89	4.94	90.00	57.21	5.70	0.093	0.033	0.034	17.47	68.20
0.00	6.46	5.80	90.00	55.43	6.62	0.082	0.026	0.027	21.51	90.27
0.00	7.06	6.63	90.00	52.48	7.51	0.071	0.021	0.022	25.93	116.61
0.00	7.71	7.43	90.00	48.90	8.35	0.061	0.018	0.018	30.73	146.81
0.00	9.16	8.89	90.00	41.63	9.86	0.043	0.013	0.014	41.53	215.77
0.00	10.77	10.17	90.00	35.51	11.16	0.027	0.011	0.011	54.14	292.28

4/4/90 ID

0.00	12.50	11.29	90.00	30.83	12.32	0.013	0.009	0.010	68.84	372.65
0.00	14.30	12.29	90.00	27.31	13.37	0.002	0.007	0.008	85.91	454.67
0.00	16.15	13.19	90.00	24.53	14.34	-0.009	0.006	0.008	105.84	538.44

PLUMES MERGING

0.00	18.04	14.00	90.00	21.99	15.30	-0.019	0.006	0.007	129.53	627.69

X	Y	Z	TH1	TH2	WIDTH	DUCL	DRHO	DCCL	TIME	DILUTION
0.00	19.97	14.70	90.00	18.15	16.39	-0.030	0.005	0.006	160.07	714.08
0.00	21.94	15.30	90.00	15.92	17.43	-0.037	0.004	0.006	199.02	794.32
0.00	23.93	15.84	90.00	14.42	18.40	-0.042	0.004	0.005	244.67	870.64
0.00	25.93	16.33	90.00	13.29	19.30	-0.045	0.003	0.005	294.45	944.11
0.00	29.95	17.21	90.00	11.63	20.94	-0.049	0.002	0.004	399.50	1083.64
0.00	33.99	18.00	90.00	10.40	22.43	-0.050	0.002	0.003	499.83	1215.97
0.00	38.05	18.70	90.00	9.40	23.82	-0.051	0.001	0.003	591.77	1341.98
0.00	42.11	19.35	90.00	8.57	25.14	-0.052	0.001	0.002	676.13	1462.30
0.00	46.19	19.93	90.00	7.84	26.40	-0.053	0.001	0.002	753.94	1577.28
0.00	50.27	20.47	90.00	7.19	27.60	-0.054	0.001	0.002	826.58	1687.25
0.00	54.35	20.97	90.00	6.62	28.79	-0.054	0.000	0.002	895.03	1792.58
0.00	58.45	21.42	90.00	6.12	29.89	-0.055	0.000	0.002	960.02	1893.57
0.00	62.54	21.84	90.00	5.65	30.84	-0.055	0.000	0.001	1021.47	1990.28
0.00	66.64	22.23	90.00	5.21	31.59	-0.054	0.000	0.001	1078.88	2082.61
0.00	74.84	22.92	90.00	4.42	35.00	-0.065	0.000	0.001	1211.50	2258.31

PLUMES HAVE REACHED EQUILIBRIUM HEIGHT - STRATIFIED ENVIRONMENT

0.00	77.67	23.14	90.00	4.16	35.96	-0.066	0.000	0.001	1264.01	2316.62
0.00	78.69	23.21	90.00	4.07	36.05	-0.065	0.000	0.001	1283.10	2337.60
0.00	79.72	23.28	90.00	3.98	36.00	-0.064	0.000	0.001	1301.12	2358.16
0.00	80.75	23.35	90.00	3.89	35.98	-0.063	0.000	0.001	1318.20	2378.29
0.00	81.77	23.42	90.00	3.80	35.98	-0.062	0.000	0.001	1334.51	2398.00
0.00	82.80	23.49	90.00	3.71	36.00	-0.061	0.000	0.001	1350.18	2417.30
0.00	83.83	23.55	90.00	3.62	36.04	-0.060	0.000	0.001	1365.31	2436.21
0.00	84.85	23.62	90.00	3.54	36.08	-0.059	0.000	0.001	1379.97	2454.74
0.00	85.88	23.68	90.00	3.45	36.14	-0.058	0.000	0.001	1394.22	2472.89
0.00	86.91	23.74	90.00	3.37	36.20	-0.058	0.000	0.001	1408.10	2490.68
0.00	87.94	23.80	90.00	3.28	36.27	-0.057	0.000	0.001	1421.66	2508.12
0.00	88.96	23.86	90.00	3.20	36.34	-0.056	0.000	0.001	1434.92	2525.20
0.00	89.99	23.92	90.00	3.12	36.41	-0.056	0.000	0.001	1447.93	2541.94
0.00	91.02	23.97	90.00	3.03	36.49	-0.055	0.000	0.001	1460.69	2558.35
0.00	92.05	24.03	90.00	2.95	36.57	-0.055	0.000	0.001	1473.23	2574.42
0.00	93.08	24.08	90.00	2.87	36.65	-0.054	0.000	0.001	1485.57	2590.17
0.00	94.10	24.13	90.00	2.79	36.73	-0.054	0.000	0.001	1497.72	2605.60
0.00	95.13	24.18	90.00	2.71	36.82	-0.053	0.000	0.001	1509.71	2620.71
0.00	96.16	24.23	90.00	2.63	36.90	-0.053	0.000	0.001	1521.53	2635.51
0.00	97.19	24.27	90.00	2.55	36.98	-0.052	0.000	0.001	1533.20	2650.00
0.00	98.22	24.32	90.00	2.48	37.07	-0.052	0.000	0.001	1544.73	2664.18
0.00	99.24	24.36	90.00	2.40	37.15	-0.052	0.000	0.001	1556.14	2678.07
0.00	100.27	24.40	90.00	2.32	37.24	-0.051	0.000	0.001	1567.42	2691.66
0.00	101.30	24.45	90.00	2.24	37.32	-0.051	0.000	0.001	1578.59	2704.95
0.00	102.33	24.49	90.00	2.17	37.40	-0.051	0.000	0.001	1589.65	2717.95
0.00	103.36	24.52	90.00	2.09	37.49	-0.050	0.000	0.001	1600.61	2730.67

0.00	104.39	24.56	90.00	2.02	37.57	-0.050	0.000	0.001	1611.48	2743.10
0.00	105.41	24.60	90.00	1.94	37.65	-0.050	0.000	0.001	1622.25	2755.25
0.00	106.44	24.63	90.00	1.87	37.73	-0.049	0.000	0.001	1632.94	2767.11
0.00	107.47	24.66	90.00	1.79	37.81	-0.049	0.000	0.001	1643.55	2778.71
0.00	108.50	24.69	90.00	1.72	37.88	-0.049	0.000	0.001	1654.08	2790.02
0.00	109.53	24.73	90.00	1.65	37.96	-0.049	0.000	0.001	1664.54	2801.07
0.00	110.56	24.75	90.00	1.57	38.04	-0.048	0.000	0.001	1674.93	2811.84
0.00	111.59	24.78	90.00	1.50	38.11	-0.048	0.000	0.001	1685.25	2822.34
0.00	112.62	24.81	90.00	1.43	38.18	-0.048	0.000	0.001	1695.51	2832.58
0.00	113.64	24.83	90.00	1.36	38.25	-0.048	0.000	0.001	1705.71	2842.56
0.00	114.67	24.86	90.00	1.28	38.32	-0.047	0.000	0.001	1715.86	2852.28

X	Y	Z	TH1	TH2	WIDTH	DUCL	DRHO	DCCL	TIME	DILUTION
0.00	115.70	24.88	90.00	1.21	38.39	-0.047	0.000	0.001	1725.95	2861.73
0.00	116.73	24.90	90.00	1.14	38.46	-0.047	0.000	0.001	1735.99	2870.93
0.00	117.76	24.92	90.00	1.07	38.52	-0.047	0.000	0.001	1745.98	2879.87
0.00	118.79	24.94	90.00	1.00	38.58	-0.047	0.000	0.001	1755.93	2888.56
0.00	119.82	24.96	90.00	0.93	38.65	-0.046	0.000	0.001	1765.82	2896.99
0.00	120.85	24.97	90.00	0.86	38.71	-0.046	0.000	0.001	1775.68	2905.18
0.00	121.88	24.99	90.00	0.79	38.76	-0.046	0.000	0.001	1785.50	2913.12
0.00	122.91	25.00	90.00	0.72	38.82	-0.046	0.000	0.001	1795.27	2920.80
0.00	123.94	25.01	90.00	0.65	38.88	-0.046	0.000	0.001	1805.01	2928.25
0.00	124.96	25.02	90.00	0.58	38.93	-0.046	0.000	0.001	1814.72	2935.45
0.00	125.99	25.03	90.00	0.52	38.98	-0.045	0.000	0.001	1824.39	2942.41
0.00	127.02	25.04	90.00	0.45	39.03	-0.045	0.000	0.001	1834.03	2949.13
0.00	128.05	25.05	90.00	0.38	39.08	-0.045	0.000	0.001	1843.63	2955.61
0.00	129.08	25.06	90.00	0.31	39.13	-0.045	0.000	0.001	1853.21	2961.86
0.00	130.11	25.06	90.00	0.25	39.17	-0.045	0.000	0.001	1862.76	2967.87
0.00	131.14	25.07	90.00	0.18	39.21	-0.045	0.000	0.001	1872.28	2973.65
0.00	132.17	25.07	90.00	0.11	39.25	-0.045	0.000	0.001	1881.78	2979.19
0.00	133.20	25.07	90.00	0.05	39.29	-0.045	0.000	0.001	1891.25	2984.51
0.00	134.23	25.07	90.00	-0.02	39.33	-0.045	0.000	0.001	1900.70	2989.61

PLUMES HAVE REACHED MAXIMUM HEIGHT - STRATIFIED ENVIRONMENT
TRAPPING LEVEL= 30.67 METERS BELOW SURFACE, DILUTION=2272.69

APPENDIX II
CDIFF MODEL INPUT/OUTPUT

****** DIFFUSION/ADVECTION MODEL FOR OCEAN DISCHARGE ******
****** EPA REGION 10 ******
****** Dye Study 1 -- Mean Flow ******

DECAY RATE = .00 DAYS**-1
DIFFUSER WIDTH = 182. FEET
OCEAN CURRENT = .6 FEET/SECOND
DISTANCE TO SHORELINE = 450. FEET
EFFLUENT CONCENTRATION = 100.
INITIAL DILUTION = 1.0

DISTANCE	EST. CONCENTRATION		EST. DILUTION	
(FEET)	C/L	S/L	C/L	S/L
100.	100.00	.00	1.0	*******
200.	99.92	.00	1.0	*******
300.	99.29	.00	1.0	*******
400.	97.77	.00	1.0	*******
500.	95.51	.00	1.0	*******
600.	92.76	.00	1.1	*******
700.	89.75	.00	1.1	*******
800.	86.63	.00	1.2	*******
900.	83.50	.00	1.2	*******
1000.	80.43	.00	1.2	*******
1100.	77.46	.00	1.3	*******
1200.	74.60	.00	1.3	*******
1300.	71.86	.00	1.4	46605.7
1400.	69.26	.01	1.4	17628.9
1500.	66.79	.01	1.5	7655.7

```
****** DIFFUSION/ADVECTION MODEL FOR OCEAN DISCHARGE ******
******                    EPA REGION 10                  ******
****** Dye Study 1 -- Mean Flow/Single Plume              ******
```

```
           DECAY RATE =       .00 DAYS**-1
       DIFFUSER WIDTH =       46. FEET
        OCEAN CURRENT =        .6 FEET/SECOND
DISTANCE TO SHORELINE =      450. FEET
EFFLUENT CONCENTRATION =     100.
     INITIAL DILUTION =       1.0
```

DISTANCE (FEET)	EST. CONCENTRATION C/L	EST. CONCENTRATION S/L	EST. DILUTION C/L	EST. DILUTION S/L
100.	99.68	.00	1.0	*******
200.	95.31	.00	1.0	*******
300.	87.83	.00	1.1	*******
400.	79.95	.00	1.3	*******
500.	72.68	.00	1.4	*******
600.	66.22	.00	1.5	*******
700.	60.56	.00	1.7	*******
800.	55.61	.00	1.8	*******
900.	51.27	.00	2.0	*******
1000.	47.45	.00	2.1	*******
1100.	44.07	.00	2.3	*******
1200.	41.07	.00	2.4	*******
1300.	38.40	.00	2.6	*******
1400.	35.99	.00	2.8	*******
1500.	33.83	.00	3.0	*******

****** DIFFUSION/ADVECTION MODEL FOR OCEAN DISCHARGE ******
****** EPA REGION 10 ******
****** Dye Study 1 -- Mean Flow -- @ Depth ******

DECAY RATE =	.00	DAYS**-1
DIFFUSER WIDTH =	185.	FEET
OCEAN CURRENT =	.3	FEET/SECOND
DISTANCE TO SHORELINE =	450.	FEET
EFFLUENT CONCENTRATION =	100.	
INITIAL DILUTION =	1.0	

DISTANCE	EST. CONCENTRATION		EST. DILUTION	
(FEET)	C/L	S/L	C/L	S/L
100.	99.95	.00	1.0	*******
200.	98.16	.00	1.0	*******
300.	93.65	.00	1.1	*******
400.	87.92	.00	1.1	*******
500.	82.01	.00	1.2	*******
600.	76.35	.00	1.3	*******
700.	71.13	.00	1.4	25411.4
800.	66.37	.02	1.5	5134.1
900.	62.05	.07	1.6	1516.0
1000.	58.15	.17	1.7	582.8
1100.	54.62	.37	1.8	271.1
1200.	51.42	.69	1.9	145.4
1300.	48.51	1.15	2.1	87.0
1400.	45.86	1.76	2.2	56.7
1500.	43.43	2.53	2.3	39.6

```
****** DIFFUSION/ADVECTION MODEL FOR OCEAN DISCHARGE ******
******                    EPA REGION 10                ******
****** Dye Study 1 -- Mean Flow/Single Plume -- @ Depth ***

               DECAY RATE =       .00 DAYS**-1
           DIFFUSER WIDTH =       46. FEET
            OCEAN CURRENT =        .3 FEET/SECOND
    DISTANCE TO SHORELINE =      450. FEET
   EFFLUENT CONCENTRATION =      100.
         INITIAL DILUTION =       1.0
```

DISTANCE (FEET)	EST. CONCENTRATION C/L	EST. CONCENTRATION S/L	EST. DILUTION C/L	EST. DILUTION S/L
100.	95.90	.00	1.0	*******
200.	81.36	.00	1.2	*******
300.	67.90	.00	1.5	*******
400.	57.34	.00	1.7	*******
500.	49.13	.00	2.0	*******
600.	42.67	.00	2.3	*******
700.	37.50	.00	2.7	*******
800.	33.28	.00	3.0	*******
900.	29.80	.00	3.4	*******
1000.	26.88	.00	3.7	*******
1100.	24.41	.00	4.1	*******
1200.	22.30	.00	4.5	*******
1300.	20.47	.00	4.9	*******
1400.	18.88	.00	5.3	*******
1500.	17.49	.00	5.7	33596.0

```
****** DIFFUSION/ADVECTION MODEL FOR OCEAN DISCHARGE ******
******                  EPA REGION 10                 ******
****** Dye Study 2 -- Mean Flow                       ******
```

```
             DECAY RATE =       .00 DAYS**-1
         DIFFUSER WIDTH =      172. FEET
          OCEAN CURRENT =        .7 FEET/SECOND
  DISTANCE TO SHORELINE =      450. FEET
 EFFLUENT CONCENTRATION =      100.
       INITIAL DILUTION =       1.0
```

DISTANCE (FEET)	EST. CONCENTRATION C/L	EST. CONCENTRATION S/L	EST. DILUTION C/L	EST. DILUTION S/L
100.	100.00	.00	1.0	*******
200.	99.97	.00	1.0	*******
300.	99.65	.00	1.0	*******
400.	98.71	.00	1.0	*******
500.	97.13	.00	1.0	*******
600.	95.05	.00	1.1	*******
700.	92.64	.00	1.1	*******
800.	90.04	.00	1.1	*******
900.	87.35	.00	1.1	*******
1000.	84.64	.00	1.2	*******
1100.	81.97	.00	1.2	*******
1200.	79.35	.00	1.3	*******
1300.	76.81	.00	1.3	*******
1400.	74.36	.00	1.3	*******
1500.	72.00	.00	1.4	*******

****** DIFFUSION/ADVECTION MODEL FOR OCEAN DISCHARGE ******
****** EPA REGION 10 ******
****** Dye Study 2 -- Mean Flow/Single Plume ******

DECAY RATE =	.00	DAYS**-1
DIFFUSER WIDTH =	43.	FEET
OCEAN CURRENT =	.7	FEET/SECOND
DISTANCE TO SHORELINE =	450.	FEET
EFFLUENT CONCENTRATION =	100.	
INITIAL DILUTION =	1.0	

DISTANCE	EST. CONCENTRATION		EST. DILUTION	
(FEET)	C/L	S/L	C/L	S/L
100.	99.86	.00	1.0	*******
200.	97.01	.00	1.0	*******
300.	91.11	.00	1.1	*******
400.	84.31	.00	1.2	*******
500.	77.67	.00	1.3	*******
600.	71.57	.00	1.4	*******
700.	66.07	.00	1.5	*******
800.	61.17	.00	1.6	*******
900.	56.81	.00	1.8	*******
1000.	52.91	.00	1.9	*******
1100.	49.43	.00	2.0	*******
1200.	46.30	.00	2.2	*******
1300.	43.48	.00	2.3	*******
1400.	40.94	.00	2.4	*******
1500.	38.63	.00	2.6	*******

****** DIFFUSION/ADVECTION MODEL FOR OCEAN DISCHARGE ******
****** EPA REGION 10 ******
****** Dye Study 2 -- Mean Flow -- @ Depth ******

DECAY RATE = .00 DAYS**-1
DIFFUSER WIDTH = 172. FEET
OCEAN CURRENT = .4 FEET/SECOND
DISTANCE TO SHORELINE = 450. FEET
EFFLUENT CONCENTRATION = 100.
INITIAL DILUTION = 1.0

DISTANCE	EST. CONCENTRATION		EST. DILUTION	
(FEET)	C/L	S/L	C/L	S/L
100.	99.97	.00	1.0	*******
200.	98.74	.00	1.0	*******
300.	95.13	.00	1.1	*******
400.	90.17	.00	1.1	*******
500.	84.81	.00	1.2	*******
600.	79.53	.00	1.3	*******
700.	74.56	.00	1.3	*******
800.	69.95	.00	1.4	90644.7
900.	65.72	.01	1.5	17764.2
1000.	61.86	.02	1.6	4942.6
1100.	58.33	.06	1.7	1771.1
1200.	55.10	.13	1.8	766.2
1300.	52.15	.26	1.9	382.8
1400.	49.44	.47	2.0	214.0
1500.	46.96	.76	2.1	130.9

```
****** DIFFUSION/ADVECTION MODEL FOR OCEAN DISCHARGE ******
******                  EPA REGION 10                ******
****** Dye Study 2 -- Mean Flow/Single Plume  -- @ Depth **
```

```
          DECAY RATE =      .00 DAYS**-1
      DIFFUSER WIDTH =      43. FEET
       OCEAN CURRENT =       .4 FEET/SECOND
DISTANCE TO SHORELINE =    450. FEET
EFFLUENT CONCENTRATION =   100.
    INITIAL DILUTION =      1.0
```

DISTANCE (FEET)	EST. CONCENTRATION C/L	EST. CONCENTRATION S/L	EST. DILUTION C/L	EST. DILUTION S/L
100.	97.05	.00	1.0	*******
200.	84.44	.00	1.2	*******
300.	71.73	.00	1.4	*******
400.	61.35	.00	1.6	*******
500.	53.09	.00	1.9	*******
600.	46.47	.00	2.2	*******
700.	41.10	.00	2.4	*******
800.	36.68	.00	2.7	*******
900.	32.99	.00	3.0	*******
1000.	29.88	.00	3.3	*******
1100.	27.23	.00	3.7	*******
1200.	24.95	.00	4.0	*******
1300.	22.97	.00	4.4	*******
1400.	21.24	.00	4.7	*******
1500.	19.72	.00	5.1	*******

APPENDIX III
CANNERY DISCHARGE DATA

AVERAGE MONTHLY LOADINGS
for
JOINT CANNERY OUTFALL
May 1992 through June 1993

DATE	TOTAL PHOSPHORUS				TOTAL NITROGEN				BOD5			
	StarKist	Van Camp	Total		StarKist	Van Camp	Total		StarKist	Van Camp	Total	
	lbs/day		lbs/day	kg/day	lbs/day		lbs/day	kg/day	mg/l		lbs/day	kg/day
May-92	53	169	222	101	1060	684	1744	791	(1)	(2)	(3)	(3)
Jun-92	41	144	185	84	970	671	1641	744				
Jul-92	35	103	138	63	686	461	1147	520				
Aug-92	39	128	167	76	775	666	1441	654				
Sep-92	42	162	204	93	751	581	1332	604				
Oct-92	39	168	207	94	644	861	1505	683				
Nov-92	45	171	216	98	512	883	1395	633	182			
Dec-92	41	107	148	67	613	593	1206	547	533			
Jan-93	33	143	176	80	594	624	1218	552	308			
Feb-93	46	154	200	91	448	690	1138	516	287			
Mar-93	110	129	239	108	827	667	1494	678	290			
Apr-93	106	108	214	97	1442	679	2121	962	186			
May-93	77	113	190	86	1184	770	1954	886	383			
Jun-93	55	126	181	82	862	668	1530	694	266			
MEAN	54	138	192	87	812	678	1490	676	304	1487	10093	4578

(1) Van Camp BOD5 effluent concentrations estimated from January and February 1992 and October November 1993 data (representing the available data bracketing the study period).
(2) StarKist BOD5 effluent concentrations estimated from data shown during the study period.

APPENDIX IV
WASTEFIELD TRANSPORT MODEL OUTPUT

PT121 Model Results

Results for the following cases are provided below. For each case the initial and final output pages are provided. The initial (time = 0) page shows the initial concentrations in each cell (initial conditions). The final page shows the predicted steady state concentration in each cell.

Case No.	Constituent	JCO Loading (kg/day)	Background Concentration (mg/l)
1	Total Nitrogen	672	0.100
2	Total Nitrogen	672	0.120
3	Total Phosphorus	87	0.013
4	Total Phosphorus	87	0.014

DISSOLVED CONSTITUENT TRANSPORT SIMULATION FOR PAGO PAGO HARBOR
Total Nitrogen-Loading of 672 kg/day - Background = 100 mg/m3
No Decay Term, Diffusivity Split at 6000 and 26000 m^2 per hour

Day: 1
Step in Day: 0
Time (hrs): 0.00
Water Level (m): -0.01
Output Interval: 960

Table of Concentrations in mg/m^3

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						100	100					
25						100	100					
24						100	100					
23						100	100					
22					100	100	100	100				
21					100	100	100	100				
20					100	100	100	100				
19					100	100	100	100				
18					100	100	100	100				
17					100	100	100	100				
16				100	100	100	100	100	100			
15				100	100	100	100	100	100			
14			100	100	100	100	100	100	100	100		
13			100	100	100	100	100	100	100	100		
12		100	100	100	100	100	100	100	100	100	100	
11		100	100	100	100	100	100	100	100	100	100	
10			100	100	100	100	100	100	100	100		
9			100	100	100	100	100	100	100	100		
8				100	100	100	100	100	100			
7				100	100	100	100	100	100			
6			100	100	100	100	100	100	100	100		
5			100	100	100	100	100	100	100	100		
4		100	100	100	100	100	100	100	100	100	100	
3		100	100	100	100	100	100	100	100	100	100	
2		100	100	100	100	100	100	100	100	100	100	
1		100	100	100	100	100	100	100	100	100	100	
0	100	100	100	100	100	100	100	100	100	100	100	100

TX-2

DISSOLVED CONSTITUENT TRANSPORT SIMULATION FOR PAGO PAGO HARBOR
Total Nitrogen-Loading of 672 kg/day - Background = 100 mg/m3
No Decay Term, Diffusivity Split at 6000 and 26000 m^2 per hour

Day: 100
Step in Day: 96
Time (hrs): 2400.00
Water Level (m): 0.56
Output Interval: 960

Table of Concentrations in mg/m^3

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						142	142					
25						142	142					
24						143	143					
23						143	143					
22					143	143	143	143				
21					143	143	143	143				
20					144	144	144	144				
19					144	144	144	144				
18					144	144	144	144				
17					144	144	144	144				
16				144	144	144	144	144	145			
15				144	144	144	145	145	145			
14			144	144	144	145	145	145	145	145		
13			144	144	144	145	145	145	145	145		
12		144	144	144	144	145	145	145	145	146	146	
11		144	144	144	144	145	145	146	146	146	146	
10			144	144	144	144	145	147	147	147		
9			143	143	143	144	146	149	149	148		
8				141	141	142	145	155	149			
7				139	138	138	140	142	140			
6			127	132	133	134	134	134	131	128		
5			122	127	129	129	128	127	125	123		
4		112	116	120	123	124	123	122	121	119	116	
3		108	111	114	116	117	117	117	116	115	114	
2		103	105	107	109	110	111	112	112	111	109	
1		101	102	103	104	105	105	106	106	105	104	
0	100	100	100	100	100	100	100	100	100	100	100	100

DISSOLVED CONSTITUENT TRANSPORT SIMULATION FOR PAGO PAGO HARBOR
Total Nitrogen-Loading of 672 kg/day - Background = 120 mg/m^
No Decay Term, Diffusivity Split at 6000 and 26000 m^2 per hour

Day: 1
Step in Day: 0
Time (hrs): 0.00
Water Level (m): -0.01
Output Interval: 960

Table of Concentrations in mg/m^3

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						120	120					
25						120	120					
24						120	120					
23						120	120					
22					120	120	120	120				
21					120	120	120	120				
20					120	120	120	120				
19					120	120	120	120				
18					120	120	120	120				
17					120	120	120	120				
16				120	120	120	120	120	120			
15				120	120	120	120	120	120			
14			120	120	120	120	120	120	120	120		
13			120	120	120	120	120	120	120	120		
12		120	120	120	120	120	120	120	120	120	120	
11		120	120	120	120	120	120	120	120	120	120	
10			120	120	120	120	120	120	120	120		
9			120	120	120	120	120	120	120	120		
8				120	120	120	120	120	120			
7				120	120	120	120	120	120			
6			120	120	120	120	120	120	120	120		
5			120	120	120	120	120	120	120	120		
4		120	120	120	120	120	120	120	120	120	120	
3		120	120	120	120	120	120	120	120	120	120	
2		120	120	120	120	120	120	120	120	120	120	
1		120	120	120	120	120	120	120	120	120	120	
0	120	120	120	120	120	120	120	120	120	120	120	120

DISSOLVED CONSTITUENT TRANSPORT SIMULATION FOR PAGO PAGO HARBOR
Total Nitrogen-Loading of 672 kg/day - Background = 120 mg/m^3
No Decay Term, Diffusivity Split at 6000 and 26000 m^2 per hour

Day: 100
Step in Day: 96
Time (hrs): 2400.00
Water Level (m): 0.56
Output Interval: 960

Table of Concentrations in mg/m^3

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						162	162					
25						162	162					
24						162	162					
23						163	163					
22					163	163	163	163				
21					163	163	163	163				
20					164	163	163	163				
19					164	164	164	164				
18					164	164	164	164				
17					164	164	164	164				
16				164	164	164	164	164	164			
15				164	164	164	164	164	164			
14			164	164	164	164	164	165	165	165		
13			164	164	164	164	165	165	165	165		
12		164	164	164	164	164	165	165	165	165	166	
11		164	164	164	164	164	165	165	166	166	166	
10			164	164	164	164	165	166	167	167		
9			163	163	163	164	165	169	168	168		
8				161	161	162	165	175	169			
7				159	158	158	160	162	160			
6			147	152	153	154	154	154	151	148		
5			142	147	149	149	148	147	145	143		
4		132	136	140	143	144	143	142	141	139	136	
3		128	131	134	136	137	137	137	136	135	134	
2		123	125	127	129	130	131	132	132	131	129	
1		121	122	123	124	125	125	126	126	125	124	
0	120	120	120	120	120	120	120	120	120	120	120	120

DISSOLVED CONSTITUENT TRANSPORT SIMULATION FOR PAGO PAGO HARBOR
Total Phosphorus-Loading of 87 kg/day - Low Background Concentration
No Decay Term, Diffusivity Split at 6000 and 26000 m^2 per hour

Day: 1
Step in Day: 0
Time (hrs): 0.00
Water Level (m): -0.01
Output Interval: 960

Table of Concentrations in mg/m^3

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						13	13					
25						13	13					
24						13	13					
23						13	13					
22					13	13	13	13				
21					13	13	13	13				
20					13	13	13	13				
19					13	13	13	13				
18					13	13	13	13				
17					13	13	13	13				
16				13	13	13	13	13	13			
15				13	13	13	13	13	13			
14			13	13	13	13	13	13	13	13		
13			13	13	13	13	13	13	13	13		
12		13	13	13	13	13	13	13	13	13	13	
11		13	13	13	13	13	13	13	13	13	13	
10			13	13	13	13	13	13	13	13		
9			13	13	13	13	13	13	13	13		
8				13	13	13	13	13	13			
7				13	13	13	13	13	13			
6			13	13	13	13	13	13	13	13		
5			13	13	13	13	13	13	13	13		
4		13	13	13	13	13	13	13	13	13	13	
3		13	13	13	13	13	13	13	13	13	13	
2		13	13	13	13	13	13	13	13	13	13	
1		13	13	13	13	13	13	13	13	13	13	
0	13	13	13	13	13	13	13	13	13	13	13	13

DISSOLVED CONSTITUENT TRANSPORT SIMULATION FOR PAGO PAGO HARBOR
Total Phosphorus-Loading of 87 kg/day - Low Background Concentration
No Decay Term, Diffusivity Split at 6000 and 26000 m^2 per hour

Day: 100
Step in Day: 96
Time (hrs): 2400.00
Water Level (m): 0.56
Output Interval: 960

Table of Concentrations in mg/m^3

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						18	18					
25						18	18					
24						18	18					
23						18	18					
22					18	18	18	18				
21					18	18	18	18				
20					18	18	18	18				
19					18	18	18	18				
18					18	18	18	18				
17					18	18	18	18				
16				18	18	18	18	18	18			
15				18	18	18	18	18	18			
14			18	18	18	18	18	18	18	18		
13			18	18	18	18	18	18	18	18		
12		18	18	18	18	18	18	18	18	19	19	
11		18	18	18	18	18	18	19	19	19	19	
10			18	18	18	18	19	19	19	19		
9			18	18	18	18	19	19	19	19		
8				18	18	18	18	20	19			
7				19	18	18	18	18	18			
6			16	17	17	17	17	17	17	16		
5			16	16	16	16	16	16	16	16		
4		14	15	15	16	16	16	15	15	15	15	
3		14	14	14	15	15	15	15	15	15	14	
2		13	13	13	14	14	14	14	14	14	14	
1		13	13	13	13	13	13	13	13	13	13	
0	13	13	13	13	13	13	13	13	13	13	13	13

DISSOLVED CONSTITUENT TRANSPORT SIMULATION FOR PAGO PAGO HARBOR
Total Phosphorus-Loading of 87 kg/day - Background = 14 mg/m^3
No Decay Term, Diffusivity Split at 6000 and 26000 m^2 per hour

Day: 1
Step in Day: 0
Time (hrs): 0.00
Water Level (m): -0.01
Output Interval: 960

Table of Concentrations in mg/m^3

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						14	14					
25						14	14					
24						14	14					
23						14	14					
22					14	14	14	14				
21					14	14	14	14				
20					14	14	14	14				
19					14	14	14	14				
18					14	14	14	14				
17					14	14	14	14				
16				14	14	14	14	14	14			
15				14	14	14	14	14	14			
14			14	14	14	14	14	14	14	14		
13			14	14	14	14	14	14	14	14		
12		14	14	14	14	14	14	14	14	14	14	
11		14	14	14	14	14	14	14	14	14	14	
10			14	14	14	14	14	14	14	14		
9			14	14	14	14	14	14	14	14		
8				14	14	14	14	14	14			
7				14	14	14	14	14	14			
6			14	14	14	14	14	14	14	14		
5			14	14	14	14	14	14	14	14		
4		14	14	14	14	14	14	14	14	14	14	
3		14	14	14	14	14	14	14	14	14	14	
2		14	14	14	14	14	14	14	14	14	14	
1		14	14	14	14	14	14	14	14	14	14	
0	14	14	14	14	14	14	14	14	14	14	14	14

DISSOLVED CONSTITUENT TRANSPORT SIMULATION FOR PAGO PAGO HARBOR
Total Phosphorus-Loading of 87 kg/day - Background = 14 mg/m3
No Decay Term, Diffusivity Split at 6000 and 26000 m^2 per hour

Day:	100
Step in Day:	96
Time (hrs):	2400.00
Water Level (m):	0.56
Output Interval:	960

Table of Concentrations in mg/m^3

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						20	20					
25						20	20					
24						20	20					
23						20	20					
22					20	20	20	20				
21					20	20	20	20				
20					20	20	20	20				
19					20	20	20	20				
18					20	20	20	20				
17					20	20	20	20				
16				20	20	20	20	20	20			
15				20	20	20	20	20	20			
14			20	20	20	20	20	20	20	20		
13			20	20	20	20	20	20	20	20		
12		20	20	20	20	20	20	20	20	20	20	
11		20	20	20	20	20	20	20	20	20	20	
10			20	20	20	20	20	20	20	20		
9			20	20	20	20	20	20	20	20		
8				20	20	20	20	21	20			
7				20	19	19	19	20	19			
6			18	19	19	19	19	18	18	18		
5			17	18	18	18	18	18	17	17		
4		16	16	17	17	17	17	17	17	17	16	
3		15	15	16	16	16	16	16	16	16	16	
2		14	15	15	15	15	15	16	16	15	15	
1		14	14	14	15	15	15	15	15	15	15	
0	14	14	14	14	14	14	14	14	14	14	14	14

APPENDIX V
WATER QUALITY MONITORING DATA

Summary of ASG Water Quality Monitoring
5/5/92 through 6/22/94
Total Nitrogen (mg/m3)

Station	Depth (ft)	Sampling Date 5/5/92	5/28/92	8/6/92	10/6/92	12-??-92	1/22/93	3/9/93	6/22/93	Mean	Max	Min
5	3	0.104	0.139	0.166	0.149	-	0.066	0.080	0.082			
	60	0.095	0.184	0.120	0.073	-	0.099	0.069	0.014			
	Avg:	*0.100*	*0.162*	*0.143*	*0.111*	-	*0.083*	*0.075*	*0.048*	*0.103*	*0.162*	*0.048*
6	3	0.122	0.272	0.132	0.078	0.138	0.124	0.041	0.122			
	60	0.115	0.111	0.130	0.151	0.103	0.094	0.035	0.122			
	Avg:	*0.119*	*0.192*	*0.131*	*0.115*	*0.121*	*0.109*	*0.038*	*0.122*	*0.118*	*0.192*	*0.038*
7	3	0.152	0.119	0.132	0.122	0.176	0.087	0.071	0.061			
	60	0.124	0.136	0.094	0.186	0.154	0.058	0.237	0.122			
	Avg:	*0.138*	*0.128*	*0.113*	*0.154*	*0.165*	*0.073*	*0.154*	*0.092*	*0.127*	*0.165*	*0.073*
8	3	0.116	0.172	0.123	0.091	0.133	0.106	0.052	0.126			
	60	0.124	0.202	0.183	0.067	0.120	0.094	0.024	0.193			
	Avg:	*0.120*	*0.187*	*0.153*	*0.079*	*0.127*	*0.100*	*0.038*	*0.160*	*0.120*	*0.187*	*0.038*
8a	3	0.087	0.142	0.175	0.137	0.150	0.133	0.035	0.109			
	60	0.120	0.286	0.169	0.156	0.141	0.155	0.164	0.160			
	Avg:	*0.104*	*0.214*	*0.172*	*0.147*	*0.146*	*0.144*	*0.100*	*0.135*	*0.145*	*0.214*	*0.100*
9	3	0.079	0.120	0.212	0.158	0.166	0.131	0.091	0.109			
	60	0.093	0.122	0.148	0.105	0.151	0.133	0.088	0.196			
	Avg:	*0.086*	*0.121*	*0.180*	*0.132*	*0.159*	*0.132*	*0.090*	*0.153*	*0.131*	*0.180*	*0.086*
9a	3	0.109	0.155	0.183	0.121	0.278	0.070	0.136	0.195			
	60	0.115	0.106	0.108	0.110	0.108	0.089	0.080	0.059			
	Avg:	*0.112*	*0.131*	*0.146*	*0.116*	*0.193*	*0.080*	*0.108*	*0.127*	*0.126*	*0.193*	*0.080*
10	3	0.146	0.122	0.160	0.117	0.138	0.089	0.088	0.225			
	60	0.124	0.112	0.134	0.113	0.097	0.102	0.028	0.293			
	Avg:	*0.135*	*0.117*	*0.147*	*0.115*	*0.118*	*0.096*	*0.058*	*0.259*	*0.131*	*0.259*	*0.058*
11	3	0.168	0.143	0.197	0.116	0.127	0.086	0.101	0.193			
	60	0.149	0.114	0.116	0.357	0.109	0.110	0.088	0.160			
	Avg:	*0.159*	*0.129*	*0.157*	*0.237*	*0.118*	*0.098*	*0.095*	*0.177*	*0.146*	*0.237*	*0.095*
11a	3	0.084	0.147	0.222	0.103	0.156	0.108	0.041	0.193			
	60	0.104	0.294	0.154	0.120	0.148	0.076	0.088	0.160			
	Avg:	*0.094*	*0.221*	*0.188*	*0.112*	*0.152*	*0.092*	*0.065*	*0.177*	*0.137*	*0.221*	*0.065*
12	3	0.097	0.103	0.221	0.172	0.188	0.170	0.071	0.252			
	60	0.112	0.061	0.237	0.179	0.183	0.131	0.052	0.193			
	Avg:	*0.105*	*0.082*	*0.229*	*0.176*	*0.186*	*0.151*	*0.062*	*0.223*	*0.151*	*0.229*	*0.062*
13	3	0.157	0.148	0.389	0.229	0.411	0.144	0.102	0.141			
	60	0.182	0.208	0.147	0.144	0.193	0.176	0.039	0.195			
	Avg:	*0.170*	*0.178*	*0.268*	*0.187*	*0.302*	*0.160*	*0.071*	*0.168*	*0.188*	*0.302*	*0.071*
14	3	0.133	0.147	0.183	0.106	0.143	0.086	0.064	0.155			
	60	0.138	0.228	0.550	0.134	0.151	0.086	0.052	0.010			
	Avg:	*0.136*	*0.188*	*0.367*	*0.120*	*0.147*	*0.086*	*0.058*	*0.083*	*0.148*	*0.367*	*0.058*
15	3	0.180	0.143	0.200	0.150	0.134	0.095	0.115	0.185			
	60	0.139	0.233	0.178	0.129	0.111	0.111	0.115	0.045			
	Avg:	*0.160*	*0.188*	*0.189*	*0.140*	*0.123*	*0.103*	*0.115*	*0.115*	*0.141*	*0.189*	*0.103*
16	3	0.103	0.164	0.337	0.183	0.114	0.130	0.039	0.036			
	60	0.166	0.115	0.150	0.137	0.103	0.097	0.147	0.095			
	Avg:	*0.135*	*0.140*	*0.244*	*0.160*	*0.109*	*0.114*	*0.093*	*0.066*	*0.132*	*0.244*	*0.066*
17	3	0.122	0.254	0.239	0.144	0.112	0.086	0.115	0.140			
	60	0.115	0.261	0.244	0.164	0.110	0.097	0.090	0.111			
	Avg:	*0.119*	*0.258*	*0.242*	*0.154*	*0.111*	*0.092*	*0.103*	*0.126*	*0.150*	*0.258*	*0.092*
18	3	0.133	0.156	0.216	0.116	0.117	0.128	0.090	0.185			
	60	0.130	0.183	0.256	0.134	0.108	0.090	0.090	0.156			
	Avg:	*0.132*	*0.170*	*0.236*	*0.125*	*0.113*	*0.109*	*0.090*	*0.171*	*0.143*	*0.236*	*0.090*

Numbers in italics are calculated depth-averaged values

Summary of ASG Water Quality Monitoring
5/5/92 through 6/22/94
Total Phosphorus (mg/m3)

Station	Depth (ft)	Sampling Date 5/5/92	5/28/92	8/6/92	10/6/92	12-??-92	1/22/93	3/9/93	6/22/93	Mean	Max	Min
	3	0.027	0.017	0.013	0.011	-	0.012	0.011	0.009			
5	60	0.023	0.014	0.004	0.001	-	0.018	0.008	0.023			
	Avg:	***0.025***	***0.016***	***0.009***	***0.006***	-	***0.015***	***0.010***	***0.016***	***0.014***	***0.025***	***0.006***
	3	0.025	0.019	0.008	0.001	0.018	0.019	0.007	0.008			
6	60	0.028	0.010	0.002	0.002	0.018	0.031	0.017	0.006			
	Avg:	***0.027***	***0.015***	***0.005***	***0.002***	***0.018***	***0.025***	***0.012***	***0.007***	***0.014***	***0.027***	***0.002***
	3	0.027	0.012	0.008	0.012	0.036	0.015	0.012	0.006			
7	60	0.026	0.016	0.003	0.016	0.018	0.011	0.006	0.010			
	Avg:	***0.027***	***0.014***	***0.006***	***0.014***	***0.027***	***0.013***	***0.009***	***0.008***	***0.015***	***0.027***	***0.006***
	3	0.021	0.024	0.014	0.008	0.016	0.019	0.016	0.013			
8	60	0.022	0.027	0.022	0.012	0.014	0.016	0.013	0.009			
	Avg:	***0.022***	***0.026***	***0.018***	***0.010***	***0.015***	***0.018***	***0.015***	***0.011***	***0.017***	***0.026***	***0.010***
	3	0.022	0.033	0.023	0.010	0.020	0.023	0.011	0.013			
8a	60	0.019	0.034	0.020	0.009	0.019	0.024	0.006	0.015			
	Avg:	***0.021***	***0.034***	***0.022***	***0.010***	***0.020***	***0.024***	***0.009***	***0.014***	***0.019***	***0.034***	***0.009***
	3	0.029	0.021	0.022	0.009	0.022	0.020	0.016	0.013			
9	60	0.033	0.023	0.011	0.012	0.020	0.019	0.006	0.014			
	Avg:	***0.031***	***0.022***	***0.017***	***0.011***	***0.021***	***0.020***	***0.011***	***0.014***	***0.018***	***0.031***	***0.011***
	3	0.025	0.020	0.016	0.010	0.034	0.010	0.009	0.012			
9a	60	0.033	0.020	0.011	0.010	0.010	0.013	0.015	0.006			
	Avg:	***0.029***	***0.020***	***0.014***	***0.010***	***0.022***	***0.012***	***0.012***	***0.009***	***0.016***	***0.029***	***0.009***
	3	0.032	0.021	0.012	0.009	0.020	0.012	0.007	0.009			
10	60	0.024	0.018	0.006	0.009	0.010	0.014	0.018	0.008			
	Avg:	***0.028***	***0.020***	***0.009***	***0.009***	***0.015***	***0.013***	***0.013***	***0.009***	***0.014***	***0.028***	***0.009***
	3	0.029	0.024	0.018	0.007	0.020	0.010	0.010	0.008			
11	60	0.032	0.021	0.005	0.041	0.016	0.014	0.019	0.009			
	Avg:	***0.031***	***0.023***	***0.012***	***0.024***	***0.018***	***0.012***	***0.015***	***0.009***	***0.018***	***0.031***	***0.009***
	3	0.021	0.024	0.016	0.008	0.026	0.014	0.023	0.010			
11a	60	0.017	0.068	0.010	0.009	0.025	0.012	0.005	0.006			
	Avg:	***0.019***	***0.046***	***0.013***	***0.009***	***0.026***	***0.013***	***0.014***	***0.008***	***0.018***	***0.046***	***0.008***
	3	0.030	0.029	0.014	0.012	0.030	0.022	0.007	0.010			
12	60	0.022	0.019	0.012	0.012	0.026	0.016	0.006	0.017			
	Avg:	***0.026***	***0.024***	***0.013***	***0.012***	***0.028***	***0.019***	***0.007***	***0.014***	***0.018***	***0.028***	***0.007***
	3	0.031	0.044	0.020	0.043	0.088	0.024	0.011	0.009			
13	60	0.028	0.052	0.010	0.017	0.027	0.028	0.014	0.006			
	Avg:	***0.030***	***0.048***	***0.015***	***0.030***	***0.058***	***0.026***	***0.013***	***0.008***	***0.028***	***0.058***	***0.008***
	3	0.032	0.001	0.011	0.001	0.014	0.017	0.011	0.017			
14	60	0.033	0.034	0.082	21.1*	0.016	0.012	0.016	0.012			
	Avg:	***0.033***	***0.018***	***0.047***		***0.015***	***0.015***	***0.014***	***0.015***	***0.022***	***0.047***	***0.014***
	3	0.026	0.025	0.018	0.017	0.014	0.016	0.013	0.006			
15	60	0.035	0.040	0.015	0.019	0.014	0.019	0.011	0.010			
	Avg:	***0.031***	***0.033***	***0.017***	***0.018***	***0.014***	***0.018***	***0.012***	***0.008***	***0.019***	***0.033***	***0.008***
	3	0.028	0.027	0.017	0.017	0.020	0.022	0.007	0.013			
16	60	0.023	0.019	0.190	0.018	0.010	0.014	0.014	0.002			
	Avg:	***0.026***	***0.023***	***0.104***	***0.018***	***0.015***	***0.018***	***0.011***	***0.008***	***0.028***	***0.104***	***0.008***
	3	0.021	0.034	0.021	0.019	0.016	0.014	0.006	0.017			
17	60	0.025	0.038	0.011	0.019	0.014	0.014	0.006	0.009			
	Avg:	***0.023***	***0.036***	***0.016***	***0.019***	***0.015***	***0.014***	***0.006***	***0.013***	***0.018***	***0.036***	***0.006***
	3	0.014	0.026	0.024	0.016	0.010	0.020	0.006	0.009			
18	60	0.029	0.026	0.036	0.018	0.012	0.017	0.004	0.011			
	Avg:	***0.022***	***0.026***	***0.030***	***0.017***	***0.011***	***0.019***	***0.005***	***0.010***	***0.017***	***0.030***	***0.005***

APPENDIX VI
REVISED PT121 MODEL SOURCE CODE

```
'lprint chr$(27)+"&a5L"
'stop
'==========================================================================

'                              PT121.BAS
'                        Version 19 June 1991
'                        Modified 22 July 1995
'==========================================================================

'==========================================================================
'                              HISTORY
'==========================================================================

'  This program was initially based on PROGRAM HARBOR (HARBOR.FOR):

'  The program HARBOR was written for the AMERICAN SAMOA ENVIRONMENTAL
'  PROTECTION AGENCY to forecast changes in nutrient levels in Pago Pago
'  harbor in response to changes in loading and outfall location. The
'  original program was written by CHARLES CHAMBERLIN AND MAC MCKEE, HYDRO
'  RESOURCES INTERNATIONAL, ARCATA, CA, 30 DECEMBER 1988.  A version of the
'  program dated 7 OCTOBER 1989 was revised by CHARLES CHAMBERLIN, 11
'  JULY 1990 (HARBOR6.FOR), to permit independent discharge locations for
'  the two cannery outfalls.  The documentation of the original program is
'  given in:

'           Chamberlin, C., M. McKee, and R. Gearheart, 1989.  "A
'           Wasteload Allocation Study for Pago Pago Harbor, American
'           Samoa".  Report prepared for American Samoa Environmental
'           Protection Agency, Pago Pago, American Samoa by
'           Hydro Resources International, Arcata, CA.

'  The program was translated from FORTRAN into TURBOBASIC and I/O routines
'  modified by STEVE COSTA/CH2M HILL (calculation algorithms were unchanged
'  and the program was validated as giving identical results as HARBOR6).

'  The program was rewritten by STEVE COSTA/CH2M HILL in AUGUST 1990 to
'  provide: two dimensional diffusive transport and axisymmetric, two
'  dimensional, bidirectional tidally driven advective transport (the
'  original first order decay terms were retained as in the original).  I/O
'  routines were completely rewritten to facilitate the new computation
'  scheme, program structure was reorganized significantly.  This version
'  of the program is documented in:

'           CH2M HILL, 1991.  "Engineering and Environmental Feasibility
'           Evaluation of Waste Disposal Alternatives". Report prepared
'           for StarKist Samoa, Inc (through StarKist Seafood Company, Long
'           Beach, CA), March 1991.

'  The program was modified in SEPTEMBER 1990 to allow application with
'  just diffusion and no water level changes or advective transport.  The
'  program was further modified in APRIL 1990 to permit a constant flow
'  rate through a system and in May 1990 to add an oxygen demand/dissolved
'  oxygen calculation and prediction routine.  The modifications were done
'  by STEVE COSTA/CH2M HILL.  This version of the model was presented at
'  an EPA Region 10 Workshop on Mixing Zone Modeling and a model descripion
'  was prepared for workshop attendees:
'
'  The program was revisded in July 1995 to allow the specification of a
'  reaction-rate constant and a value of DO at saturation by Steve Costa.
```

```
'++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
'
'                         INITIALIZE AND INPUT DATA
'
'++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
'Initialize and Setup
'--------------------
PIE = 3.14159265
cls

dim TP(30),XA(30),TB(30),TQ(30),PQOUT(20,30),AX(30),DVOL(30),QX(30),VX(30)
dim TYDE(2000,2),PQ(30)
dim CI(30),EK(30),KD(30),NPL(30),IS%(30),IE%(30),D(20,30),IB%(80),JB%(80)
dim PSL(20,30),BCN%(80),IOUT%(20),JOUT%(30),DVDT(20,30)
dim COLD(20,30),CNEW(20,30),TG%(20,30),BG%(20,30),RG%(20,30),LG%(20,30)
dim IN%(30), AI(20,30),AJ(20,30),VIJ(20,30),DCDT(9,20),QIN(20,30),QOUT(20,30)
dim IDO(30), DOX(20,30),CCOLD(20,30),DCCOLD(20,30)

'Input Name Of JCL File
'----------------------
print "Default Job Control List File Name is JCLPT121."
print "Press <RETURN> with No Entry to Use this File."
input "Otherwise Enter File Name then <RETURN>";JCLNAM$
if JCLNAM$ = "" then JCLNAM$ = "JCLPT121"


'Input Job Control Data
'----------------------
NRUN% = 1
NEXTCASE:

print "NOW READING JOB CONTROL DATA."
open JCLNAM$ for input as #2

input #2, JCLNAM$
input #2, NCASES%

for N% = 1 to NRUN%

   input #2, HYDNAM$
   input #2, TIDNAM$
   input #2, WQNAM$
   input #2, OUTFILE$
   input #2, HYOUTFILE$
   input #2, PTOUTFILE$

   for I% = 1 to 3: input #2, TITLE$(I%): next I%
   input #2, IMAX%,JMAX%
   input #2, DT,DX
   input #2, IDAY0%,IDAYN%
   input #2, NOUT%,NTIDE%
   input #2, IOC%(1)
   for I% = 2 to IOC%(1): input #2, IOC%(I%): next I%

   for J% = 0 to JMAX%
      for I% = 0 to IMAX%
         PQOUT(I%,J%)=0
         PSL(I%,J%)=0
      next I%
   next J%

   for J% = 1 to NOUT%
      input #2, JOUT%(J%),IOUT%(J%)
      input #2, PQOUT(IOUT%(J%),JOUT%(J%)),PSL(IOUT%(J%),JOUT%(J%))
   next J%
```

```
next N%

close #2
NRUN% = NRUN% + 1

if IOC%(2) = 1 then gosub OUTTITLE:

'Input Hydrodynamics/Geometric Data
'----------------------------------
if NTIDE%=0 then goto SKIPHYDIN:
print "NOW READING HYDRO DATA."
open hydnam$ for input as #2

input #2, hydnam$
input #2, RQ
RQ = 0.043813*RQ*3600

for I% = 1 to JMAX%
   input #2, XA(I%),TP(I%),TB(I%)
next I%

for J% = 1 to JMAX%
   PQ(J%) = 0
   for I% = 1 to IMAX%
      PQ(J%) = PQ(J%) + PQOUT(I%,J%)
   next I%
   TQ(J%) = 3600 * (TB(J%) + 0.043813*PQ(J%))
next J%

close #2

if IOC%(3) = 1 then gosub OUTHYDRO:
if NTIDE% = -1 then goto SKIPHYDIN:

'Input Tidal Data
'----------------
open TIDNAM$ for input as #2
input #2, TIDNAM$
print "NOW READING TIDES."

for I% = 1 to NTIDE%
   input #2, TYDE(I%,1),TYDE(I%,2)
next I%

close #2

if IOC%(4) = 1 then gosub OUTTIDE:
SKIPHYDIN:

'Input Water Quality/Geometric Data
'----------------------------------
print "NOW READING WATER QUALITY DATA."
open WQNAM$ for input as #2
input #2, WQNAM$, KRDO, DOEFF, DOSAT

if IOC%(8) = 1 then
   for J% = 0 to JMAX%
      input#2, J,CI(J%), EK(J%), KD(J%), NPL(J%),IDO(J%)
      for I% = 0 to IMAX%
         DOX(I%,J%) = IDO(J%)
      next I%
   next J%
else
   for J% = 0 to JMAX%
      input#2, J,CI(J%), EK(J%), KD(J%), NPL(J%)
```

```
   next J%
end if

for J% = 1 to JMAX%-1
  input #2, J,IS%(J%),IE%(J%)
  IN%(J%) = IE%(J%) - IS%(J%) + 1
next J%
IS%(0) = IS%(1): IE%(0) = IE%(1): IN%(0) = IN%(1)
IS%(JMAX%) = IS%(JMAX%-1): IE%(JMAX%) = IE%(JMAX%-1)
IN%(JMAX%) = IN%(JMAX%-1)

for J% = 0 to JMAX%
   input #2, J
   for I% = 0 to IMAX%
      input #2, D(I%,J%)
      D(I%,J%) = D(I%,J%)*0.3048
      VIJ(I%,J%) = D(I%,J%)*DX*DX
   next I%
next J%

input #2, NBC%
for KB% = 1 to NBC%
   input #2, KB%,IB%(KB%),JB%(KB%),BCN%(KB%)
next KB%

close #2
if IOC%(5) = 1 then gosub OUTWQ:

'Set Clock and Get First Water Level Elevation
'----------------------------------------------
IPOINT = 1
IDAY%  = IDAY0%
IHR%   = 0
T      = (IDAY0%-1)*24
HOLD   = 0
DH     = 0
HNEW   = 0
if NTIDE%=0 or NTIDE% = -1 then goto SKIPITIDE:
gosub PAGOTIDE
TOLD = T
HOLD = H
SKIPITIDE:
'Set Initial Conditions
'----------------------
for J% = 0 to JMAX%
   for I% = 0 to IMAX%
      if IOC%(8) = 1 then
         CCOLD(I%,J%) = CI(J%)
      elseif IOC%(8) = 0 then
         COLD(I%,J%) = CI(J%)
      end if
   next I%
next J%

'Set Boundary Conditions for Constituent Diffusion
'-------------------------------------------------
for J% = 1 to JMAX%-1
   for I% = IS%(J%) to IE%(J%)
      TG%(I%,J%) = 1
      BG%(I%,J%) = 1
      LG%(I%,J%) = 1
      RG%(I%,J%) = 1
   next I%
next J%
```

```
for KB% = 1 to NBC%
   I%=IB%(KB%)
   J%=JB%(KB%)
   select case BCN%(KB%)
   case 1                                'Closed Left and Bottom
      LG%(I%,J%) = 0
      BG%(I%,J%) = 0
   case 2                                'Closed Bottom
      BG%(I%,J%) = 0
   case 3                                'Closed Right and Bottom
      RG%(I%,J%) = 0
      BG%(I%,J%) = 0
   case 4                                'Closed Left
      LG%(I%,J%) = 0
   case 5                                'Closed Right
      RG%(I%,J%) = 0
   case 6                                'Closed Left and Top
      LG%(I%,J%) = 0
      TG%(I%,J%) = 0
   case 7                                'Closed Right and Top
      RG%(I%,J%) = 0
      TG%(I%,J%) = 0
   case 8                                'Closed Top
      TG%(I%,J%) = 0
   end select
next KB%

'+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
'
'                         MAIN DRIVER ROUTINE
'              BEGIN ITERATION LOOP (SIMULATE TIME SEQUENCE)
'
'+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
IHRMAX% = int(24/DT)
if 24/DT <> int(24/DT) then
   print "TIME INCREMENT MUST BE INTEGER FRACTION OF DAY"
   print "Program run has been terminated!!"
   stop
end if
print "BEGINNING SIMULATION."
if IOC%(7) > 0 then gosub OUTCONCALC
if IOC%(8) > 0 then gosub OUTDOCALC

for IDAY% = IDAY0% to IDAYN%
   for IHR% = 1 to IHRMAX%
      T = T + DT

      'Get VX and AX for Next Time Step
      '--------------------------------
      if NTIDE% <> 0 then gosub HYDRO:
      CSTEP% = CSTEP% + 1
      if IOC%(6) = 0 then
         exit if
      elseif CSTEP%/IOC%(6) = int(CSTEP%/IOC%(6)) then
         gosub OUTHYDCALC:
      end if

      'Calculate Concentrations for Next Time Step
      '-------------------------------------------
      gosub CONCCALC:
      if IOC%(8) = 1 then gosub DOCALC
      if IOC%(7) = 0 then
         exit if
      elseif CSTEP%/IOC%(7) = int(CSTEP%/IOC%(7)) then
```

```
            gosub OUTCONCALC:
         if IOC%(8) = 1 then gosub OUTDOCALC:
      end if

   next IHR%
next IDAY%

if NRUN% =< NCASES% then goto NEXTCASE:

END


'++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
'
'          HYDRO CALCUATION ROUTINES CALLED FROM MAIN DRIVER
'
'++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

'------------------------------------------------------------------------
'       SUBROUTINE TO COMPUTE VELOCITIES AND CROSS SECTIONAL AREAS
'------------------------------------------------------------------------
HYDRO:

'Get Tide Elevation at Next Time Step
'------------------------------------
if NTIDE% > 0 THEN
   gosub PAGOTIDE:
   HNEW = H
end if

'Compute Flows into Each LineCell
'--------------------------------
DH = HNEW - HOLD
DVOL(JMAX%-1) = ((TP(JMAX%)+TP(JMAX%-1))*.5*DX*DH)
QX(JMAX%-1) = (DVOL(JMAX%-1) / DT) - TQ(JMAX%-1) - RQ
for J% = (JMAX%-2) to 1 step -1
   DVOL(J%) = ((TP(J%)+TP(J%+1))*.5*DX*DH)
   QX(J%) = (DVOL(J%) / DT) - TQ(J%) + QX(J%+1)
next J%


'Compute Cross Sectional Areas and Velocities
'--------------------------------------------
for J%= 1 to (JMAX%-1)
   AX(J%) = XA(J%) + HNEW * TP(J%)
   VX(J%) = QX(J%) / AX(J%)
next J%


'Set Hydro Boundary Condition at end of Harbor
'---------------------------------------------
AX(JMAX%) = XA(JMAX%) + HNEW * TP(JMAX%)
QX(JMAX%) = -RQ
VX(JMAX%) = -RQ/AX(JMAX%)


'Push Time and Elevations into Previous Step
'-------------------------------------------
HOLD = HNEW
TOLD = T


'Calculate Unit Flows for Each Cell from LineCell Flows
'------------------------------------------------------
for J% = 1 to JMAX%-1
```

```
'Flow Into Cells
'---------------
'Flood Tide
'----------
if DH > 0 then
   if IN%(J%) = IN%(J%-1) then
      for I% = IS%(J%) to IE%(J%)
         QIN(I%,J%) = (QX(J%)/IN%(J%))
      next I%
   elseif IN%(J%) < IN%(J%-1) then
      for I% = IS%(J%) to IE%(J%)
         QIN(I%,J%) = (QX(J%)/IN%(J%))
      next I%
   elseif IN%(J%) > IN%(J%-1) then
      RCN% = IN%(J%)/2
      QSF% = IN%(J%-1)/2
      QIN(IS%(J%),J%) = (QX(J%)/IN%(J%))
      QIN(IE%(J%),J%) = (QX(J%)/IN%(J%))
      RCN% = RCN%-1
      for I% = (IS%(J%)+1) to (IS%(J%)+(IN%(J%)/2)-1) step 1
         QIN(I%,J%) =    (QX(J%)/IN%(J%-1))_
                       - (RCN%/QSF%)*(QX(J%)/IN%(J%))_
                       + ((RCN%-1)/QSF%)*(QX(J%)/IN%(J%))
         RCN% = RCN%-1
      next I%
      RCN% = IN%(J%)/2-1
      for I% = (IE%(J%)-1) to (IE%(J%)-(IN%(J%)/2)+1) step -1
         QIN(I%,J%) =    (QX(J%)/IN%(J%-1))_
                       - (RCN%/QSF%)*(QX(J%)/IN%(J%))_
                       + ((RCN%-1)/QSF%)*(QX(J%)/IN%(J%))
         RCN% = RCN%-1
      next I%
   end if

'Ebb Tide
'--------
elseif DH <= 0 then
   if IN%(J%) = IN%(J%+1) then
      for I% = IS%(J%) to IE%(J%)
         QIN(I%,J%) = -(QX(J%+1)/IN%(J%))
      next I%
   elseif IN%(J%) < IN%(J%+1) then
      for I% = IS%(J%) to IE%(J%)
         QIN(I%,J%) = -(QX(J%+1)/IN%(J%))
      next I%
   elseif IN%(J%) > IN%(J%+1) then
      RCN% = IN%(J%)/2
      QSF% = IN%(J%+1)/2
      QIN(IS%(J%),J%) = -((QX(J%+1)/IN%(J%)))
      QIN(IE%(J%),J%) = -((QX(J%+1)/IN%(J%)))
      RCN% = RCN%-1
      for I% = (IS%(J%)+1) to (IS%(J%)+(IN%(J%)/2)-1) step 1
         QIN(I%,J%) = -  (QX(J%+1)/IN%(J%+1))_
                       + (RCN%/QSF%)*(QX(J%+1)/IN%(J%))_
                       - ((RCN%-1)/QSF%)*(QX(J%+1)/IN%(J%))
         RCN% = RCN%-1
      next I%
      RCN% = IN%(J%)/2-1
      for I% = (IE%(J%)-1) to (IE%(J%)-(IN%(J%)/2)+1) step -1
         QIN(I%,J%) = -  (QX(J%+1)/IN%(J%+1))_
                       + (RCN%/QSF%)*(QX(J%+1)/IN%(J%))_
                       - ((RCN%-1)/QSF%)*(QX(J%+1)/IN%(J%))
         RCN% = RCN%-1
      next I%
   end if
```

```
end if

'Flow Out of Cells
'-----------------
'Flood Tide
'----------
if DH > 0 then
   if IN%(J%) = IN%(J%+1) then
      for I% = IS%(J%) to IE%(J%)
         QOUT(I%,J%) = -((QX(J%+1)/IN%(J%)))
      next I%
   elseif IN%(J%) < IN%(J%+1) then
      for I% = IS%(J%) to IE%(J%)
         QOUT(I%,J%) = -((QX(J%+1)/IN%(J%)))
      next I%
   elseif IN%(J%) > IN%(J%+1) then
      RCN% = IN%(J%)/2
      QSF% = IN%(J%+1)/2
      QOUT(IS%(J%),J%) = -((QX(J%+1)/IN%(J%)))
      QOUT(IE%(J%),J%) = -((QX(J%+1)/IN%(J%)))
      RCN% = RCN%-1
      for I% = (IS%(J%)+1) to (IS%(J%)+(IN%(J%)/2)-1) step 1
         QOUT(I%,J%) = -(QX(J%+1)/IN%(J%+1))_
                     + (RCN%/QSF%)*(QX(J%+1)/IN%(J%))_
                     - ((RCN%-1)/QSF%)*(QX(J%+1)/IN%(J%))
         RCN% = RCN%-1
      next I%
      RCN% = IN%(J%)/2-1
      for I% = (IE%(J%)-1) to (IE%(J%)-(IN%(J%)/2)+1) step -1
         QOUT(I%,J%) = -(QX(J%+1)/IN%(J%+1))_
                     + (RCN%/QSF%)*(QX(J%+1)/IN%(J%))_
                     - ((RCN%-1)/QSF%)*(QX(J%+1)/IN%(J%))
         RCN% = RCN%-1
      next I%
   end if

'Ebb Tide
'--------
elseif DH <= 0 then
   if IN%(J%) = IN%(J%-1) then
      for I% = IS%(J%) to IE%(J%)
         QOUT(I%,J%) = ((QX(J%)/IN%(J%)))
      next I%
   elseif IN%(J%) < IN%(J%-1) then
      for I% = IS%(J%) to IE%(J%)
         QOUT(I%,J%) = ((QX(J%)/IN%(J%)))
      next I%
   elseif IN%(J%) > IN%(J%-1) then
      RCN% = IN%(J%)/2
      QSF% = IN%(J%-1)/2
      QOUT(IS%(J%),J%) = ((QX(J%)/IN%(J%)))
      QOUT(IE%(J%),J%) = ((QX(J%)/IN%(J%)))
      RCN% = RCN%-1
      for I% = (IS%(J%)+1) to (IS%(J%)+(IN%(J%)/2)-1) step 1
         QOUT(I%,J%) = + (QX(J%)/IN%(J%-1))_
                       - (RCN%/QSF%)*(QX(J%)/IN%(J%))_
                       + ((RCN%-1)/QSF%)*(QX(J%)/IN%(J%))
         RCN% = RCN%-1
      next I%
      RCN% = IN%(J%)/2-1
      for I% = (IE%(J%)-1) to (IE%(J%)-(IN%(J%)/2)+1) step -1
         QOUT(I%,J%) = + (QX(J%)/IN%(J%-1))_
                       - (RCN%/QSF%)*(QX(J%)/IN%(J%))_
                       + ((RCN%-1)/QSF%)*(QX(J%)/IN%(J%))
         RCN% = RCN%-1
```

```
         next I%
      end if
   end if

next J%

return

'-------------------------------------------------------------------------
'          SUBROUTINE TO COMPUTE TIDES AT PAGO PAGO HARBOR
'             (Using Data Table Lookup and Interpolation)
'-------------------------------------------------------------------------
PAGOTIDE:
if T < TYDE(1,1) or T > TYDE(NTIDE%,1) then
   print "TIDAL ERROR DUE TO INPUT START/STOP DAYS.  PROGRAM ABORTED."
   stop
end if

if T < TYDE(IPOINT,1) then IPOINT = 1
TIDESEARCH:
KP = IPOINT
KP1 = KP + 1
TL = TYDE(KP,1)
TR = TYDE(KP1,1)
if TL  <= T and T <= TR then
   HL = TYDE(KP,2)
   HR = TYDE(KP1,2)
   A  = 0.5 * (HL - HR)
   B  = 0.5 * (HL + HR)
   DTRL = TR - TL
   C  = PIE * (T - TL) / DTRL
   H  = B + A * COS(C)
else
   IPOINT = IPOINT + 1
   goto TIDESEARCH:
end if

H = H / 3.28084

return


'+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
'
'        TRANSPORT CALCULATION ROUTINES CALLED FROM MAIN DRIVER
'
'+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

'-------------------------------------------------------------------------
'              ROUTINE TO CALCULATE TRANSPORT COMPONENTS
'-------------------------------------------------------------------------
CONCCALC:
CPASS% = 0
if IOC%(8) = 1 then
   for J% = 0 to JMAX%
      for I% = 0 to IMAX%
         COLD(I%,J%) = CCOLD(I%,J%)
      next I%
   next J%
   CPASS% = 1
end if
goto STARTCALC:

DOCALC:
if IOC%(8) = 1 then
```

```
   for J% = 0 to JMAX%
      for I% = 0 to IMAX%
         COLD(I%,J%) = DOX(I%,J%)
      next I%
   next J%
   CPASS% = 2
end if

STARTCALC:
'Calculate Diffusive Transport Areas and Cell Volumes
'---------------------------------------------------
for J%=1 to JMAX%-1
   for I% = IS%(J%) to IE%(J%)
      DVDT(I%,J%) = QIN(I%,J%) + QOUT(I%,J%) + (TQ(J%)/IN%(J%))
      VIJ(I%,J%) = VIJ(I%,J%)  + (DVDT(I%,J%)*DT)
      AI(I%,J%) = (((D(I%-1,J%)+D(I%,J%))/2)+DH)*DX
      AJ(I%,J%) = (((D(I%,J%-1)+D(I%,J%))/2)+DH)*DX
   next I%
next J%

'Calculate Terms in Mass Balance Equation
'----------------------------------------
for J%=1 to JMAX%-1
if NTIDE%=0 then goto SKIPAD:

   for I% = IS%(J%) to IE%(J%)

     '(1) Volume change
     '-----------------
     DCDT(1,I%) = -COLD(I%,J%)*DVDT(I%,J%)/VIJ(I%,J%)

   next I%

'goto skip1:

   'Calculate Advective Terms
   'DCDT(2,I%) and DCDT(3,I%)
   '-------------------------

   if DH = 0 and RQ = 0 then goto SKIPAD:
   gosub ADVECTION:

SKIPAD:
'skip1:

   for I% = IS%(J%) to IE%(J%)

'goto skip:

     '(4) Y-Directed Diffusion In
     '---------------------------
     if BG%(I%,J%) = 0 then
        DCDT(4,I%) = 0
     else
        DCDT(4,I%) = -(AJ(I%,J%)*EK(J%)/VIJ(I%,J%)) * ((COLD(I%,J%)-COLD(I%,J%-1))/DX)
     end if

     '(5) Y-Directed Diffusion Out
     '----------------------------
     if TG%(I%,J%) = 0 then
        DCDT(5,I%) = 0
     else
        DCDT(5,I%) = (AJ(I%,J%+1)*EK(J%+1)/VIJ(I%,J%)) * ((COLD(I%,J%+1)-COLD(I%,J%))/DX)
     end if
```

```
    '(6) X-Directed Diffusion In
    '---------------------------
    if LG%(I%,J%) = 0 then
       DCDT(6,I%) = 0
    else
       DCDT(6,I%) = -(AI(I%,J%)*EK(J%)/VIJ(I%,J%)) * ((COLD(I%,J%)-COLD(I%-1,J%))/DX)
    end if

    '(7) X-Directed Diffusion Out
    '----------------------------
    if RG%(I%,J%) = 0 then
       DCDT(7,I%) = 0
    else
       DCDT(7,I%) = (AI(I%+1,J%)*EK(J%)/VIJ(I%,J%)) * ((COLD(I%+1,J%)-COLD(I%,J%))/DX)
    end if

  next I%

'skip:
'goto skip2:

  for I% = IS%(J%) to IE%(J%)

    '(8) Decay
    '---------
    if CPASS% = 0 then
       DCDT(8,I%) = -KD(J%)*COLD(I%,J%)
    elseif CPASS% = 1 then
       DCDT(8,I%) = -KD(J%)*COLD(I%,J%)
       DCCOLD(I%,J%) = DCDT(8,I%)
    elseif CPASS% = 2 then
       DCDT(8,I%) = DCCOLD(I%,J%)/1000
    end if

  next I%

'skip2:

  for I% = IS%(J%) to IE%(J%)

    '(9) External Input
    '------------------
    if CPASS% = 0 or CPASS% = 1 then
       if I% = IS% or IE% then NPS=(NPL(J%)/2)*(10^6/24) else NPS=0
       if PSL(I%,J%) > 0 then PSS=PSL(I%,J%)*(10^6/24) else PSS=0
       if PSL(I%,J%) =-1 then PSS=COLD(I%,J%)*PQOUT(I%,J%)*157.7*DT
       DCDT(9,I%) =  (NPS+PSS)/VIJ(I%,J%)
    elseif CPASS% = 2 then
       if PSL(I%,J%) > 0 then PSSDO=DOEFF*PQOUT(I%,J%)*(157.7)*DT else PSSDO=0
       if PSL(I%,J%) =-1 then PSSDO=COLD(I%,J%)*PQOUT(I%,J%)*157.7*DT
       DCDT(9,I%) =  (PSSDO/VIJ(I%,J%))+KRDO*(DOSAT-COLD(I%,J%))
    end if

  next I%

'skip:

  for I% = IS%(J%) to IE%(J%)

    'Calculate New Concentration
    '---------------------------
    DCDT=0
    for K%=1 to 9: DCDT=DCDT+DCDT(K%,I%): next K%
    CNEW(I%,J%) = COLD(I%,J%) + DT*DCDT
    if CSTEP%/IOC%(7) = int(CSTEP%/IOC%(7)) then
```

```
         'width "LPT1:",130
         'lprint IDAY%;IHR%;I%;J%;cnew(i%,j%);qin(i%,j%);qout(i%,j%);
         'lprint dvdt(i%,j%)
         print IDAY%;IHR%;I%;J%;cnew(i%,j%)

     end if

   next I%

next J%


'Push New Concentration Values into Previous Step
'-------------------------------------------------
for J% = 1 to JMAX%-1
   for I% = IS%(J%) to IE%(J%)
      if CPASS%=0 then
         COLD(I%,J%)=CNEW(I%,J%)
      elseif CPASS% = 1 then
         CCOLD(I%,J%)=CNEW(I%,J%)
      elseif CPASS% = 2 then
         DOX(I%,J%) = CNEW(I%,J%)
      end if
   next I%
next J%

return

'---------------------------------------------------------------------------
'          ROUTINE TO CALCULATE ADVECTIVE TRANSPORT TERMS
'---------------------------------------------------------------------------
   ADVECTION:
   '(2) Advective Transport In
   '--------------------------

   'Flood Tide
   '----------
   if (DH=> 0) or (DH=0 and RQ<0) then
      if IN%(J%) = IN%(J%-1) then
         for I% = IS%(J%) to IE%(J%)
            DCDT(2,I%) = ((QX(J%)/IN%(J%))*COLD(I%,J%-1))/VIJ(I%,J%)
         next I%
      elseif IN%(J%) < IN%(J%-1) then
         for I% = IS%(J%) to IE%(J%)
            DCDT(2,I%) = ((QX(J%)/IN%(J%))*COLD(I%,J%-1))/VIJ(I%,J%)
         next I%
      elseif IN%(J%) > IN%(J%-1) then
         RCN% = IN%(J%)/2
         QSF% = IN%(J%-1)/2
         DCDT(2,IS%(J%)) = ((QX(J%)/IN%(J%))*COLD(IS%(J%)+1,J%))/VIJ(IS%(J%),J%)
         DCDT(2,IE%(J%)) = ((QX(J%)/IN%(J%))*COLD(IE%(J%)-1,J%))/VIJ(IE%(J%),J%)
         RCN% = RCN%-1
         for I% = (IS%(J%)+1) to (IS%(J%)+(IN%(J%)/2)-1) step 1
            DCDT(2,I%) = (QX(J%)/IN%(J%-1))*COLD(I%,J%-1)_
                       - (RCN%/QSF%)*(QX(J%)/IN%(J%))*COLD(I%,J%)_
                       + ((RCN%-1)/QSF%)*(QX(J%)/IN%(J%))*COLD(I%+1,J%)
            DCDT(2,I%) = DCDT(2,I%)/VIJ(I%,J%)
            RCN% = RCN%-1
         next I%
         RCN% = IN%(J%)/2-1
         for I% = (IE%(J%)-1) to (IE%(J%)-(IN%(J%)/2)+1) step -1
            DCDT(2,I%) = (QX(J%)/IN%(J%-1))*COLD(I%,J%-1)_
                       - (RCN%/QSF%)*(QX(J%)/IN%(J%))*COLD(I%,J%)_
                       + ((RCN%-1)/QSF%)*(QX(J%)/IN%(J%))*COLD(I%-1,J%)
            DCDT(2,I%) = DCDT(2,I%)/VIJ(I%,J%)
```

```
            RCN% = RCN%-1
         next I%
      end if

   'Ebb Tide
   '--------
   elseif (DH<0) or (DH=0 and Rq>0) then
      if IN%(J%) = IN%(J%+1) then
         for I% = IS%(J%) to IE%(J%)
            DCDT(2,I%) = -((QX(J%+1)/IN%(J%))*COLD(I%,J%+1))/VIJ(I%,J%)
         next I%
      elseif IN%(J%) < IN%(J%+1) then
         for I% = IS%(J%) to IE%(J%)
            DCDT(2,I%) = -((QX(J%+1)/IN%(J%))*COLD(I%,J%+1))/VIJ(I%,J%)
         next I%
      elseif IN%(J%) > IN%(J%+1) then
         RCN% = IN%(J%)/2
         QSF% = IN%(J%+1)/2
         DCDT(2,IS%(J%)) = -((QX(J%+1)/IN%(J%))*COLD(IS%(J%)+1,J%))/VIJ(IS%(J%),J%)
         DCDT(2,IE%(J%)) = -((QX(J%+1)/IN%(J%))*COLD(IE%(J%)-1,J%))/VIJ(IE%(J%),J%)
         RCN% = RCN%-1
         for I% = (IS%(J%)+1) to (IS%(J%)+(IN%(J%)/2)-1) step 1
            DCDT(2,I%) = (QX(J%+1)/IN%(J%+1))*COLD(I%,J%+1)_
                         - (RCN%/QSF%)*(QX(J%+1)/IN%(J%))*COLD(I%,J%)_
                         + ((RCN%-1)/QSF%)*(QX(J%+1)/IN%(J%))*COLD(I%+1,J%)
            DCDT(2,I%) = -DCDT(2,I%)/VIJ(I%,J%)
            RCN% = RCN%-1
         next I%
         RCN% = IN%(J%)/2-1
         for I% = (IE%(J%)-1) to (IE%(J%)-(IN%(J%)/2)+1) step -1
            DCDT(2,I%) = (QX(J%+1)/IN%(J%+1))*COLD(I%,J%+1)_
                         - (RCN%/QSF%)*(QX(J%+1)/IN%(J%))*COLD(I%,J%)_
                         + ((RCN%-1)/QSF%)*(QX(J%+1)/IN%(J%))*COLD(I%-1,J%)
            DCDT(2,I%) = -DCDT(2,I%)/VIJ(I%,J%)
            RCN% = RCN%-1
         next I%
      end if
   end if

   '(3) Advective Transport Out
   '---------------------------
   'Flood Tide
   '----------
   if (DH > 0) or (DH=0 and RQ<0) then
      if IN%(J%) = IN%(J%+1) then
         for I% = IS%(J%) to IE%(J%)
            DCDT(3,I%) = -((QX(J%+1)/IN%(J%))*COLD(I%,J%))/VIJ(I%,J%)
         next I%
      elseif IN%(J%) < IN%(J%+1) then
         for I% = IS%(J%) to IE%(J%)
            DCDT(3,I%) = -((QX(J%+1)/IN%(J%))*COLD(I%,J%))/VIJ(I%,J%)
         next I%
      elseif IN%(J%) > IN%(J%+1) then
         RCN% = IN%(J%)/2
         QSF% = IN%(J%+1)/2
         DCDT(3,IS%(J%)) = -((QX(J%+1)/IN%(J%))*COLD(IS%(J%),J%))/VIJ(IS%(J%),J%)
         DCDT(3,IE%(J%)) = -((QX(J%+1)/IN%(J%))*COLD(IE%(J%),J%))/VIJ(IE%(J%),J%)
         RCN% = RCN%-1
         for I% = (IS%(J%)+1) to (IS%(J%)+(IN%(J%)/2)-1) step 1
            DCDT(3,I%) = -(QX(J%+1)/IN%(J%+1))*COLD(I%,J%)_
                         + (RCN%/QSF%)*(QX(J%+1)/IN%(J%))*COLD(I%-1,J%)_
                         - ((RCN%-1)/QSF%)*(QX(J%+1)/IN%(J%))*COLD(I%,J%)
            DCDT(3,I%) = DCDT(3,I%)/VIJ(I%,J%)
            RCN% = RCN%-1
         next I%
```

```
         RCN% = IN%(J%)/2-1
         for I% = (IE%(J%)-1) to (IE%(J%)-(IN%(J%)/2)+1) step -1
            DCDT(3,I%) = -(QX(J%+1)/IN%(J%+1))*COLD(I%,J%)_
                         + (RCN%/QSF%)*(QX(J%+1)/IN%(J%))*COLD(I%+1,J%)_
                         - ((RCN%-1)/QSF%)*(QX(J%+1)/IN%(J%))*COLD(I%,J%)
            DCDT(3,I%) = DCDT(3,I%)/VIJ(I%,J%)
            RCN% = RCN%-1
         next I%
      end if

   'Ebb Tide
   '--------
   elseif (DH < 0) or (DH=0 and RQ>0) then
      if IN%(J%) = IN%(J%-1) then
         for I% = IS%(J%) to IE%(J%)
            DCDT(3,I%) = ((QX(J%)/IN%(J%))*COLD(I%,J%))/VIJ(I%,J%)
         next I%
      elseif IN%(J%) < IN%(J%-1) then
         for I% = IS%(J%) to IE%(J%)
            DCDT(3,I%) = ((QX(J%)/IN%(J%))*COLD(I%,J%))/VIJ(I%,J%)
         next I%
      elseif IN%(J%) > IN%(J%-1) then
         RCN% = IN%(J%)/2
         QSF% = IN%(J%-1)/2
         DCDT(3,IS%(J%)) = ((QX(J%)/IN%(J%))*COLD(IS%(J%),J%))/VIJ(IS%(J%),J%)
         DCDT(3,IE%(J%)) = ((QX(J%)/IN%(J%))*COLD(IE%(J%),J%))/VIJ(IE%(J%),J%)
         RCN% = RCN%-1
         for I% = (IS%(J%)+1) to (IS%(J%)+(IN%(J%)/2)-1) step 1
            DCDT(3,I%) = -(QX(J%)/IN%(J%-1))*COLD(I%,J%)_
                         + (RCN%/QSF%)*(QX(J%)/IN%(J%))*COLD(I%-1,J%)_
                         - ((RCN%-1)/QSF%)*(QX(J%)/IN%(J%))*COLD(I%,J%)
            DCDT(3,I%) = -DCDT(3,I%)/VIJ(I%,J%)
            RCN% = RCN%-1
         next I%
         RCN% = IN%(J%)/2-1
         for I% = (IE%(J%)-1) to (IE%(J%)-(IN%(J%)/2)+1) step -1
            DCDT(3,I%) = -(QX(J%)/IN%(J%-1))*COLD(I%,J%)_
                         + (RCN%/QSF%)*(QX(J%)/IN%(J%))*COLD(I%+1,J%)_
                         - ((RCN%-1)/QSF%)*(QX(J%)/IN%(J%))*COLD(I%,J%)
            DCDT(3,I%) = -DCDT(3,I%)/VIJ(I%,J%)
            RCN% = RCN%-1
         next I%
      end if
   end if

   return

'------------------------------------------
'FUNCTION TO ACCOUNT FOR DIRECTION OF FLOW
'[C = Flow, A and B are adjacent conc's]
'------------------------------------------
'def FNdir(A,B,C)
'   if  C <= 0 then
'      FNdir=B
'   else
'      FNdir=A
'   end if
'end def


'++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
'
'                            OUTPUT SUBROUTINES
'
```

```
'+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

'-------------------------------------------------------------------------
'          OUTPUT ROUTINES FOR MODEL SETUP AND INPUT DATA
'-------------------------------------------------------------------------
'Routine to output title page
'----------------------------
OUTTITLE:
open OUTFILE$ for output as #1
if OUTFILE$="LPT1:" then lprint chr$(27)+"&a10L"

for I% = 1 to 3
   print #1, TITLE$(I%)
next I%
print #1,

print #1, "Job Control File is:                   ";JCLNAM$
print #1, "Hydrodynamics/Geometric File is:       ";HYDNAM$
print #1, "Tidal Data File is:                    ";TIDNAM$
print #1, "Water Quality/Geometric File is:       ";WQNAM$
print #1, "Output File is:                        ";OUTFILE$
print #1, "Hydro Output File is:                  ";HYOUTFILE$
print #1, "Concentrations Output File is:         ";PTOUTFILE$
print #1,

print #1, "Model grid is";IMAX%; "wide and";JMAX%; "long."
print #1,
print #1, "Time Increment in hours              =";
print #1, using "##";DT
print #1, "Length Increment in meters           =";
print #1, using "####";DX
print #1, "Start day in tide table              =";IDAY0%
print #1, "End day in tide table                =";IDAYN%
print #1, "Number of point source discharges =";NOUT%
print #1, "Number of tidal extrema used         =";NTIDE%
print #1,
print #1, "I/O control string is:";
for I% = 1 to IOC%(1): print #1, using "##";IOC%(I%);: next I%
print #1, chr$(12)

close #1
return


'Routine to Output Hydro/Geo Data
'--------------------------------
OUTHYDRO:
open "A", #1,OUTFILE$
if OUTFILE$="LPT1:" then lprint chr$(27)+"&a10L"

for I% = 1 to 3
   print #1, TITLE$(I%)
next I%
print #1,
print #1, "Riverine Flow = ";
print #1, using "###.#####";RQ/3600;
print #1, "(m^3/s) = ";
print #1, using "###.##   ";RQ/(3600*0.043813);
print #1, "(mgd)"
print #1,
print #1,
print #1, "Node  Surface    Cross-sectional    Nonpoint    Point source    Total"
print #1, " No.   Width          Area           Inflow        Inflow       Inflow"
print #1, "        (m)          (m^2)          (m^3/s)        (mgd)       (m^3/hr)"
print #1, "----  --------  ---------------    ---------  ------------   --------"
```

```
K% = 1
for I% = 1 to JMAX%
   print #1, using "###";I%;
   print #1, using "    ######";TP(I%);
   print #1, using "      ##########";XA(I%);
   print #1, using "          ###.###";TB(I%);
   if JOUT%(K%) = I% then
      print #1, using "       #####.##";PQ(I%);
      K% = K% + 1
   else
      print #1, "              ";
   end if
   print #1, using "     ####.###";TQ(I%)
next I%
print #1, chr$(12)

close #1
return


'Routine to Output Tidal Level Data
'-----------------------------------
OUTTIDE:
open "A", #1,OUTFILE$
if OUTFILE$="LPT1:" then lprint chr$(27)+"&a10L"

for I% = 1 to 3
   print #1, TITLE$(I%)
next I%
print #1,
print #1,

print #1, "Number of Tidal Extrema Used =";NTIDE%
print #1,

for J% = 1 to 3: print #1, "  Time    Elevation  ";: next J%: print #1,
for J% = 1 to 3: print #1, "  (hrs)   (ft)   (m)  ";: next J%: print #1,
for J% = 1 to 3: print #1, "-------  ----  ----  ";: next J%: print #1,

for I% = 1 to NTIDE% step 3
   for J% = 0 to 2
      print #1, using "####.##";TYDE(I%+J%,1);
      print #1, using "###.##";TYDE(I%+J%,2);
      print #1, using "###.##  ";TYDE(I%+J%,2)*0.3048;
   next J%
   print #1,
next I%
print #1, chr$(12)

close #1
return

'Routine to Output Water Quality/Geo Data
'----------------------------------------
OUTWQ:
open "A", #1,OUTFILE$
if OUTFILE$="LPT1:" then lprint chr$(27)+"&a5L"

for I% = 1 to 3
   print #1, TITLE$(I%)
next I%
print #1,
print #1,

print #1, "Cell  Initial   Diffusivity Decay   Initial  Nonpoint  Point Souce"
```

```
print #1, "Line    Conc       Coeff.       Rate      DO    Loading     Loading  "
print #1, "        (mg/m^3)   (m^2/hr)     (1/hr)  (mg/l)  (kg/day)    (kg/day) "
print #1, "----   --------  -----------  ------  -------  --------  -----------"
for J% = JMAX%-1 to 1 step -1
   print #1, using "###    ";J%;
   print #1, using " ###.##    ";CI(J%);
   print #1, using "  #######     ";EK(J%);
   print #1, using "#.####   ";KD(J%);
   print #1, using " ##.## ";IDO(J%);
   print #1, using " ##.### ";NPL(J%);
   for I% = IS%(J%) to IE%(J%)
      if PSL(I%,J%) <> 0 then
         print #1, tab(47)
         print #1, using "##### ";PSL(I%,J%);
         print #1, " @ I=";
         print #1, I%
      end if
   next I%
   print #1,
next J%
print #1, chr$(12)

print #1, "Table of Cell Depths in Meters"
print #1,
print #1, "J/I ";
for I% = 0 to IMAX%: print #1, using "  ### ";I%;: next I%: print #1,
print #1, "___ ";
for I% = 0 to IMAX%: print #1, "_____ ";: next I%: print #1,
for J% = JMAX% to 0 step -1
   print #1, using "### ";J%;
   for I% = 0 to IMAX%
      print #1, using "##.## ";D(I%,J%);
   next I%
   print #1,
next J%
print #1, chr$(12)

print #1, "Table of Boundary Conditions"
print #1,

for J% = 1 to 3: print #1, "  I     J     BC    ";: next J%: print #1,
for J% = 1 to 3: print #1, " ----  ----  ----   ";: next J%: print #1,

for I% = 1 to NBC% step 3
   for J% = 0 to 2
      print #1, using " ###  ";IB%(I%+J%);JB%(I%+J%);BCN%(I%+J%);
      print #1, "  ";
   next J%
   print #1,
next I%
print #1,
print #1,
print #1, "(BC is Boundary Condition Designator)"

print #1, chr$(12)

close #1
return

'-----------------------------------------------------------------------------
'            OUTPUT ROUTINES FOR RESULTS OF MODEL RUN
'-----------------------------------------------------------------------------
'Routine to Output Hydro Calculations
'-------------------------------------
OUTHYDCALC:
```

```
open HYOUTFILE$ for append as #3
if HYOUTFILE$="LPT1:" then lprint chr$(27)+"&a10L"

for I% = 1 to 3
   print #3, TITLE$(I%)
next I%
print #3,
print #3,

print #3, "Day:                ";IDAY%
print #3, "Hour:               ";IHR%
print #3, "Time (hrs):         ";:print #3, using "######.##";T
print #3, "Water Level (m):    ";:print #3, using "####.####";HNEW
print #3, "Output Interval:    ";:print #3, IOC%(6)
print #3,

print #3, "Cell  Change in Volume  Flow Rate  XSection Area  Velocity"
print #3, "            (m^3)         (m^3/hr)      (m^2)        (m/hr)
print #3, "----  ----------------  ---------  -------------  --------"
for J% = JMAX% to 1 step -1
   print #3, using "###";J%;
   print #3, using "        ######";DVOL(J%);
   print #3, using "        ########";QX(J%);
   print #3, using "         #####";AX(J%);
   print #3, using "      ####.##";VX(J%)
next J%

print #3, chr$(12)

close #3
return

'Routine to Output Concentration Calculations
'--------------------------------------------
OUTCONCALC:

if CPASS% = 0 then
   for J% = 1 to JMAX%-1
      for I% = IS%(J%) to IE%(J%)
         CCOLD(I%,J%)=COLD(I%,J%)
      next I%
   next J%
end if

open PTOUTFILE$ for append as #4
if PTOUTFILE$ = "LPT1:" then lprint chr$(27)+"&a5L"

for I% = 1 to 3
   print #4, TITLE$(I%)
next I%
print #4,
print #4,

print #4, "Day:                ";IDAY%
print #4, "Step in Day:        ";IHR%
print #4, "Time (hrs):         ";:print #4, using "######.##";T
print #4, "Water Level (m):    ";:print #4, using "######.##";H
print #4, "Output Interval:    ";:print #4, IOC%(7)
print #4,
print #4,

print #4, "Table of Concentrations in mg/m^3"
print #4,
print #4, "J/I ";
for I% = 0 to IMAX%: print #4, using "  ### ";I%;: next I%: print #4,
```

```
print #4, "___ ";
for I% = 0 to IMAX%: print #4, "_____ ";: next I%: print #4,

print #4, using "### ";JMAX%;
for I% = 0 to IS%(JMAX%-1)-1:print #4, "      ";:next I%
for I% = IS%(JMAX%-1) to IE%(JMAX%-1)
   if TG%(I%,JMAX%-1)=1 then print #4, spc(6); else print #4, "______";
next I%
print #4,

for J% = JMAX%-1 to 1 step -1
   print #4, using "### ";J%;
   for I% = 0 to IMAX%
      if I% =(IS%(J%)-1) then
         print #4, "     |";
      elseif I% =(IE%(J%)+1) then
         print #4, "|";
      elseif I% < (IS%(J%)-1) or I% > (IE%(J%)+1) then
         print #4, spc(6);
      elseif I%=>IS%(J%) and I%=<IE%(J%) then
         print #4, using "##### ";CCOLD(I%,J%);
      end if
   next I%
   print #4,
next J%

print #4, using "### ";0;
for I% = 0 to IMAX%
   print #4, using "##### ";CCOLD(I%,0);
next I%
print #4,

print #4, chr$(12)

close #4
return

'Routine to Output Dissolved Oxygen Calculations
'-----------------------------------------------
OUTDOCALC:
open PTOUTFILE$ for append as #4
if PTOUTFILE$ = "LPT1:" then lprint chr$(27)+"&a5L"

for I% = 1 to 3
   print #4, TITLE$(I%)
next I%
print #4,
print #4,

print #4, "Day:                 ";IDAY%
print #4, "Step in Day:         ";IHR%
print #4, "Time (hrs):          ";:print #4, using "######.##";T
print #4, "Water Level (m):     ";:print #4, using "######.##";H
print #4, "Output Interval:     ";:print #4, IOC%(7)
print #4,
print #4,

print #4, "Table of Dissolved Oxygen Concentrations in mg/l"
print #4,
print #4, "J/I ";
for I% = 0 to IMAX%: print #4, using "  ### ";I%;: next I%: print #4,
print #4, "___ ";
for I% = 0 to IMAX%: print #4, "_____ ";: next I%: print #4,

print #4, using "### ";JMAX%;
```

```
for I% = 0 to IS%(JMAX%-1)-1:print #4, "      ";:next I%
for I% = IS%(JMAX%-1) to IE%(JMAX%-1)
   if TG%(I%,JMAX%-1)=1 then print #4, spc(6); else print #4, "______";
next I%
print #4,

for J% = JMAX%-1 to 1 step -1
   print #4, using "### ";J%;
   for I% = 0 to IMAX%
      if I% =(IS%(J%)-1) then
         print #4, "     |";
      elseif I% =(IE%(J%)+1) then
         print #4, "|";
      elseif I% < (IS%(J%)-1) or I% > (IE%(J%)+1) then
         print #4, spc(6);
      elseif I%=>IS%(J%) and I%=<IE%(J%) then
         print #4, using "##.## ";DOX(I%,J%);
      end if
   next I%
   print #4,
next J%

print #4, using "### ";0;
for I% = 0 to IMAX%
   print #4, using "##### ";DOX(I%,0);
next I%
print #4,

print #4, chr$(12)

close #4
return
```

APPENDIX VII
BOD-DO MODEL RESULTS

BOD - DISSOLVED OXYGEN SIMULATION FOR PAGO PAGO HARBOR
Model Run No. 5 - Reference Case - Nominal Kr (0.00528/hr)
BODu = 0000 kg/day - K = 0.0152/hr - Diffusivity @6000 & 26000 m^2/hr)

Day: 25
Step in Day: 96
Time (hrs): 600.00
Water Level (m): 0.55
Output Interval: 2400

Table of Dissolved Oxygen Concentrations in mg/l

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						6.11	6.11					
25						6.12	6.12					
24						6.13	6.13					
23						6.14	6.14					
22					6.14	6.14	6.14	6.14				
21					6.14	6.14	6.14	6.14				
20					6.14	6.14	6.14	6.14				
19					6.14	6.14	6.14	6.14				
18					6.14	6.14	6.14	6.14				
17					6.13	6.13	6.13	6.13				
16				6.12	6.12	6.12	6.12	6.12	6.12			
15				6.12	6.12	6.12	6.12	6.12	6.12			
14			6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12		
13			6.11	6.11	6.12	6.12	6.12	6.11	6.11	6.11		
12		6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	
11		6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	
10			6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10		
9			6.10	6.10	6.10	6.10	6.10	6.09	6.09	6.10		
8				6.09	6.09	6.09	6.09	6.09	6.09			
7				6.08	6.08	6.08	6.08	6.08	6.08			
6			6.06	6.07	6.07	6.07	6.07	6.07	6.07	6.06		
5			6.05	6.06	6.07	6.07	6.06	6.06	6.06	6.06		
4		6.03	6.04	6.05	6.06	6.06	6.06	6.05	6.05	6.05	6.04	
3		6.02	6.03	6.04	6.04	6.04	6.04	6.04	6.04	6.04	6.04	
2		6.01	6.02	6.02	6.02	6.03	6.03	6.03	6.03	6.03	6.03	
1		6.01	6.01	6.01	6.01	6.01	6.02	6.02	6.02	6.01	6.01	
0	6	6	6	6	6	6	6	6	6	6	6	6

BOD - DISSOLVED OXYGEN SIMULATION FOR PAGO PAGO HARBOR
Model Run No. 5 - Reference Case - Nominal Kr (0.00528/hr)
BODu = 0000 kg/day - K = 0.0152/hr - Diffusivity @6000 & 26000 m^2/hr)

Day: 50
Step in Day: 96
Time (hrs): 1200.00
Water Level (m): 0.42
Output Interval: 2400

Table of Dissolved Oxygen Concentrations in mg/l

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						6.12	6.12					
25						6.12	6.12					
24						6.13	6.13					
23						6.14	6.14					
22					6.14	6.14	6.14	6.14				
21					6.14	6.14	6.14	6.14				
20					6.14	6.14	6.14	6.14				
19					6.14	6.14	6.14	6.14				
18					6.14	6.14	6.14	6.14				
17					6.13	6.13	6.13	6.13				
16				6.12	6.12	6.12	6.12	6.12	6.12			
15				6.12	6.12	6.12	6.12	6.12	6.12			
14			6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12		
13			6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11		
12		6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	
11		6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	
10			6.11	6.10	6.10	6.10	6.10	6.10	6.10	6.10		
9			6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10		
8				6.09	6.09	6.09	6.09	6.09	6.09			
7				6.08	6.08	6.08	6.08	6.08	6.08			
6			6.07	6.08	6.07	6.07	6.07	6.07	6.07	6.07		
5			6.06	6.07	6.07	6.07	6.06	6.06	6.06	6.06		
4		6.05	6.06	6.06	6.06	6.06	6.05	6.05	6.05	6.05	6.05	
3		6.04	6.05	6.05	6.04	6.04	6.04	6.04	6.04	6.04	6.04	
2		6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	
1		6.02	6.02	6.02	6.02	6.02	6.02	6.02	6.02	6.02	6.02	
0	6	6	6	6	6	6	6	6	6	6	6	6

BOD - DISSOLVED OXYGEN SIMULATION FOR PAGO PAGO HARBOR
Model Run No. 6 - Nominal Case - Nominal Kr (0.01532/hr)
BODu = 6684 kg/day - K = 0.0152/hr - Diffusivity @6000 & 26000 m^2/hr)

Day: 25
Step in Day: 96
Time (hrs): 600.00
Water Level (m): 0.55
Output Interval: 2400

Table of Concentrations in mg/m^3

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						9	9					
25						10	10					
24						12	12					
23						14	14					
22					17	17	17	17				
21					20	20	20	20				
20					26	25	24	25				
19					33	31	31	32				
18					41	39	39	40				
17					51	50	50	50				
16				66	65	65	65	65	67			
15				70	69	69	69	71	71			
14			77	75	74	74	75	77	79	82		
13			81	80	80	81	82	84	86	88		
12		85	85	86	87	88	90	92	95	97	99	
11		88	90	92	94	98	102	106	108	111	104	
10			97	98	103	109	118	129	132	134		
9			101	105	110	120	137	170	168	153		
8				108	113	124	153	249	197			
7				101	106	113	129	155	148			
6			75	87	93	97	102	109	103	87		
5			61	74	80	82	81	80	75	69		
4		36	45	56	64	66	65	62	58	53	46	
3		24	31	38	44	46	47	46	45	42	38	
2		11	15	20	25	28	29	31	32	30	26	
1		5	6	9	11	13	15	16	17	14	12	
0	0	0	0	0	0	0	0	0	0	0	0	0

BOD - DISSOLVED OXYGEN SIMULATION FOR PAGO PAGO HARBOR
Model Run No. 6 - Nominal Case - Nominal Kr (0.01532/hr)
BODu = 6684 kg/day - K = 0.0152/hr - Diffusivity @6000 & 26000 m^2/hr)

Day: 25
Step in Day: 96
Time (hrs): 600.00
Water Level (m): 0.55
Output Interval: 2400

Table of Dissolved Oxygen Concentrations in mg/l

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						6.15	6.15					
25						6.15	6.15					
24						6.16	6.16					
23						6.17	6.17					
22					6.17	6.17	6.17	6.17				
21					6.16	6.16	6.16	6.16				
20					6.16	6.16	6.16	6.16				
19					6.15	6.15	6.15	6.15				
18					6.14	6.14	6.14	6.14				
17					6.13	6.23	6.13	6.13				
16				6.12	6.12	6.12	6.12	6.12	6.12			
15				6.11	6.12	6.12	6.12	6.11	6.11			
14			6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11		
13			6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11		
12		6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	
11		6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	
10			6.10	6.10	6.10	6.09	6.09	6.09	6.09	6.09		
9			6.09	6.09	6.09	6.09	6.09	6.09	6.08	6.09		
8				6.08	6.08	6.08	6.08	6.08	6.08			
7				6.08	6.08	6.08	6.08	6.08	6.07			
6			6.07	6.07	6.07	6.07	6.07	6.07	6.07	6.07		
5			6.06	6.07	6.07	6.07	6.07	6.06	6.06	6.06		
4		6.04	6.05	6.05	6.06	6.06	6.06	6.06	6.06	6.05	6.05	
3		6.03	6.04	6.04	6.05	6.05	6.05	6.05	6.05	6.05	6.04	
2		6.02	6.02	6.03	6.03	6.03	6.04	6.04	6.04	6.04	6.03	
1		6.01	6.01	6.01	6.02	6.02	6.02	6.02	6.02	6.02	6.02	
0	6	6	6	6	6	6	6	6	6	6	6	6

BOD - DISSOLVED OXYGEN SIMULATION FOR PAGO PAGO HARBOR
Model Run No. 6 - Nominal Case - Nominal Kr (0.01532/hr)
BODu = 6684 kg/day - K = 0.0152/hr - Diffusivity @6000 & 26000 m^2/hr)

Day: 50
Step in Day: 96
Time (hrs): 1200.00
Water Level (m): 0.42
Output Interval: 2400

Table of Concentrations in mg/m^3

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						10	10					
25						11	11					
24						12	12					
23						14	14					
22					18	17	17	18				
21					21	20	20	20				
20					25	25	25	25				
19					33	32	31	31				
18					41	40	39	40				
17					50	50	50	49				
16				65	64	64	64	64	66			
15				69	69	69	69	70	70			
14			76	74	74	74	75	77	77	79		
13			79	80	80	81	82	83	84	85		
12		84	84	85	86	88	90	91	92	93	96	
11		85	88	90	93	96	100	102	102	102	99	
10			93	96	100	106	115	122	120	117		
9			97	101	107	116	133	160	151	134		
8				105	110	121	150	245	192			
7				102	104	112	130	163	159			
6			84	91	92	96	103	115	116	103		
5			75	79	80	80	80	82	81	79		
4		53	62	66	66	65	63	61	60	57	50	
3		46	49	49	49	47	46	45	45	43	42	
2		34	33	31	30	29	29	31	33	33	32	
1		19	16	15	14	14	15	17	19	19	19	
0	0	0	0	0	0	0	0	0	0	0	0	0

BOD - DISSOLVED OXYGEN SIMULATION FOR PAGO PAGO HARBOR
Model Run No. 6 - Nominal Case - Nominal Kr (0.01532/hr)
BODu = 6684 kg/day - K = 0.0152/hr - Diffusivity @6000 & 26000 m^2/hr)

Day: 50
Step in Day: 96
Time (hrs): 1200.00
Water Level (m): 0.42
Output Interval: 2400

Table of Dissolved Oxygen Concentrations in mg/l

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						6.15	6.15					
25						6.15	6.15					
24						6.16	6.16					
23						6.17	6.17					
22					6.16	6.17	6.17	6.16				
21					6.16	6.16	6.16	6.16				
20					6.16	6.16	6.16	6.16				
19					6.15	6.15	6.15	6.15				
18					6.14	6.14	6.14	6.14				
17					6.13	6.13	6.13	6.13				
16				6.12	6.12	6.12	6.12	6.12	6.12			
15				6.11	6.12	6.12	6.12	6.12	6.11			
14			6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11		
13			6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11		
12		6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	
11		6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	
10			6.10	6.10	6.10	6.09	6.09	6.09	6.09	6.09		
9			6.09	6.09	6.09	6.09	6.09	6.09	6.09	6.09		
8				6.09	6.08	6.08	6.08	6.08	6.08			
7				6.08	6.08	6.08	6.08	6.08	6.07			
6			6.07	6.07	6.07	6.07	6.07	6.07	6.07	6.07		
5			6.07	6.07	6.07	6.07	6.07	6.06	6.06	6.06		
4		6.06	6.06	6.06	6.06	6.06	6.06	6.06	6.06	6.06	6.05	
3		6.05	6.05	6.05	6.05	6.05	6.05	6.05	6.05	6.05	6.05	
2		6.04	6.04	6.04	6.04	6.04	6.04	6.04	6.04	6.04	6.04	
1		6.03	6.02	6.02	6.02	6.02	6.02	6.02	6.03	6.03	6.03	
0	6	6	6	6	6	6	6	6	6	6	6	6

BOD - DISSOLVED OXYGEN SIMULATION FOR PAGO PAGO HARBOR
Model Run No. 7 - Nominal Case - Reduced Kr (0.00528/hr)
BODu = 6684 kg/day - K = 0.0152/hr - Diffusivity @6000 & 26000 m^2/hr)

Day: 25
Step in Day: 96
Time (hrs): 600.00
Water Level (m): 0.55
Output Interval: 2400

Table of Concentrations in mg/m^3

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						9	9					
25						10	10					
24						12	12					
23						14	14					
22					17	17	17	17				
21					20	20	20	20				
20					26	25	24	25				
19					33	31	31	32				
18					41	39	39	40				
17					51	50	50	50				
16				66	65	65	65	65	67			
15				70	69	69	69	71	71			
14			77	75	74	74	75	77	79	82		
13			81	80	80	81	82	84	86	88		
12		85	85	86	87	88	90	92	95	97	99	
11		88	90	92	94	98	102	106	108	111	104	
10			97	98	103	109	118	129	132	134		
9			101	105	110	120	137	170	168	153		
8				108	113	124	153	249	197			
7				101	106	113	129	155	148			
6			75	87	93	97	102	109	103	87		
5			61	74	80	82	81	80	75	69		
4		36	45	56	64	66	65	62	58	53	46	
3		24	31	38	44	46	47	46	45	42	38	
2		11	15	20	25	28	29	31	32	30	26	
1		5	6	9	11	13	15	16	17	14	12	
0	0	0	0	0	0	0	0	0	0	0	0	0

BOD - DISSOLVED OXYGEN SIMULATION FOR PAGO PAGO HARBOR
Model Run No. 7 - Nominal Case - Reduced Kr (0.00528/hr)
BODu = 6684 kg/day - K = 0.0152/hr - Diffusivity @6000 & 26000 m^2/hr)

Day: 25
Step in Day: 96
Time (hrs): 600.00
Water Level (m): 0.55
Output Interval: 2400

Table of Dissolved Oxygen Concentrations in mg/l

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						6.03	6.03					
25						6.03	6.03					
24						6.04	6.04					
23						6.04	6.04					
22					6.04	6.04	6.04	6.04				
21					6.04	6.04	6.04	6.04				
20					6.03	6.03	6.03	6.03				
19					6.02	6.02	6.02	6.02				
18					6.01	6.01	6.01	6.01				
17					6.00	6.00	6.00	6.00				
16				5.99	5.99	5.99	5.99	5.99	5.99			
15				5.99	5.99	5.99	5.99	5.99	5.99			
14			5.98	5.98	5.98	5.98	5.98	5.98	5.98	5.98		
13			5.98	5.98	5.98	5.98	5.98	5.98	5.98	5.98		
12		5.98	5.98	5.98	5.98	5.98	5.98	5.98	5.98	5.98	5.98	
11		5.98	5.98	5.98	5.98	5.98	5.98	5.98	5.98	5.98	5.98	
10			5.98	5.98	5.98	5.98	5.98	5.98	5.98	5.97		
9			5.98	5.98	5.98	5.98	5.98	5.98	5.97	5.97		
8				5.98	5.98	5.98	5.98	5.98	5.98			
7				5.98	5.98	5.98	5.98	5.98	5.98			
6			5.99	5.98	5.98	5.98	5.98	5.98	5.98	5.99		
5			5.99	5.99	5.99	5.99	5.99	5.99	5.99	5.99		
4		5.99	5.99	5.99	5.99	5.99	5.99	5.99	5.99	5.99	5.99	
3		6.00	5.99	5.99	5.99	5.99	5.99	5.99	5.99	6.00	6.00	
2		6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	
1		6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	
0	6	6	6	6	6	6	6	6	6	6	6	6

BOD - DISSOLVED OXYGEN SIMULATION FOR PAGO PAGO HARBOR
Model Run No. 7 - Nominal Case - Reduced Kr (0.00528/hr)
BODu = 6684 kg/day - K = 0.0152/hr - Diffusivity @6000 & 26000 m^2/hr)

Day: 50
Step in Day: 96
Time (hrs): 1200.00
Water Level (m): 0.42
Output Interval: 2400

Table of Concentrations in mg/m^3

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						10	10					
25						11	11					
24						12	12					
23						14	14					
22					18	17	17	18				
21					21	20	20	20				
20					25	25	25	25				
19					33	32	31	31				
18					41	40	39	40				
17					50	50	50	49				
16				65	64	64	64	64	66			
15				69	69	69	69	70	70			
14			76	74	74	74	75	77	77	79		
13			79	80	80	81	82	83	84	85		
12		84	84	85	86	88	90	91	92	93	96	
11		85	88	90	93	96	100	102	102	102	99	
10			93	96	100	106	115	122	120	117		
9			97	101	107	116	133	160	151	134		
8				105	110	121	150	245	192			
7				102	104	112	130	163	159			
6			84	91	92	96	103	115	116	103		
5			75	79	80	80	80	82	81	79		
4		53	62	66	66	65	63	61	60	57	50	
3		46	49	49	49	47	46	45	45	43	42	
2		34	33	31	30	29	29	31	33	33	32	
1		19	16	15	14	14	15	17	19	19	19	
0	0	0	0	0	0	0	0	0	0	0	0	0

BOD - DISSOLVED OXYGEN SIMULATION FOR PAGO PAGO HARBOR
Model Run No. 7 - Nominal Case - Reduced Kr (0.00528/hr)
BODu = 6684 kg/day - K = 0.0152/hr - Diffusivity @6000 & 26000 m^2/hr)

Day: 50
Step in Day: 96
Time (hrs): 1200.00
Water Level (m): 0.42
Output Interval: 2400

Table of Dissolved Oxygen Concentrations in mg/l

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						6.03	6.03					
25						6.03	6.03					
24						6.04	6.04					
23						6.04	6.04					
22					6.04	6.04	6.04	6.04				
21					6.04	6.04	6.04	6.04				
20					6.03	6.03	6.03	6.03				
19					6.02	6.02	6.02	6.02				
18					6.01	6.01	6.01	6.01				
17					6.00	6.00	6.00	6.00				
16				5.99	5.99	5.99	5.99	5.99	5.99			
15				5.99	5.99	5.99	5.99	5.99	5.99			
14			5.98	5.98	5.98	5.98	5.98	5.98	5.98	5.98		
13			5.98	5.98	5.98	5.98	5.98	5.98	5.98	5.98		
12		5.98	5.98	5.98	5.98	5.98	5.98	5.98	5.98	5.98	5.98	
11		5.98	5.98	5.98	5.98	5.98	5.98	5.98	5.98	5.98	5.98	
10			5.98	5.98	5.98	5.98	5.98	5.98	5.98	5.98		
9			5.98	5.98	5.98	5.98	5.98	5.98	5.97	5.97		
8				5.98	5.98	5.98	5.98	5.98	5.98			
7				5.98	5.98	5.98	5.98	5.98	5.98			
6			5.98	5.98	5.98	5.98	5.98	5.98	5.98	5.98		
5			5.99	5.99	5.99	5.99	5.99	5.99	5.99	5.99		
4		5.99	5.99	5.99	5.99	5.99	5.99	5.99	5.99	5.99	5.99	
3		5.99	5.99	5.99	5.99	5.99	5.99	5.99	6.00	6.00	6.00	
2		5.99	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	
1		6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	
0	6	6	6	6	6	6	6	6	6	6	6	6

BOD - DISSOLVED OXYGEN SIMULATION FOR PAGO PAGO HARBOR
Model Run No. 9 - Extreme Case Loading - Nominal Kr (0.01532/hr)
BODu = 20000 kg/day - K = 0.0152/hr - Diffusivity @6000 & 26000 m^2/hr)

Day: 25
Step in Day: 96
Time (hrs): 600.00
Water Level (m): 0.55
Output Interval: 2400

Table of Concentrations in mg/m^3

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						28	28					
25						31	31					
24						36	36					
23						42	42					
22					52	49	50	52				
21					61	59	59	59				
20					77	74	73	74				
19					99	93	92	95				
18					123	118	117	121				
17					152	151	150	150				
16				198	194	194	194	195	201			
15				209	207	207	208	211	214			
14			230	225	222	223	225	230	235	245		
13			241	240	239	241	244	250	257	263		
12		255	255	256	259	264	270	276	283	291	296	
11		262	271	274	281	292	305	316	323	332	312	
10			289	294	307	326	354	387	396	401		
9			303	314	330	358	411	508	503	459		
8				323	337	371	459	744	589			
7				302	316	339	386	465	442			
6			223	261	278	291	306	325	307	261		
5			184	222	239	245	244	239	226	208		
4		108	135	167	193	197	194	185	175	159	137	
3		72	93	113	132	139	139	139	135	125	114	
2		33	45	61	75	83	88	93	95	89	77	
1		14	19	26	33	39	44	47	50	43	35	
0	0	0	0	0	0	0	0	0	0	0	0	0

BOD - DISSOLVED OXYGEN SIMULATION FOR PAGO PAGO HARBOR
Model Run No. 9 - Extreme Case Loading - Nominal Kr (0.01532/hr)
BODu = 20000 kg/day - K = 0.0152/hr - Diffusivity @6000 & 26000 m^2/hr)

Day: 25
Step in Day: 96
Time (hrs): 600.00
Water Level (m): 0.55
Output Interval: 2400

Table of Dissolved Oxygen Concentrations in mg/l

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						6.11	6.10					
25						6.11	6.11					
24						6.11	6.11					
23						6.11	6.11					
22					6.10	6.10	6.10	6.10				
21					6.09	6.09	6.09	6.09				
20					6.07	6.08	6.08	6.08				
19					6.06	6.06	6.06	6.06				
18					6.03	6.04	6.04	6.04				
17					6.01	6.02	6.02	6.02				
16				5.99	5.99	5.99	5.99	5.99	5.99			
15				5.98	5.98	5.98	5.98	5.98	5.98			
14			5.97	5.98	5.98	5.98	5.98	5.98	5.97	5.97		
13			5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97		
12		5.96	5.97	5.97	5.97	5.97	5.97	5.97	5.96	5.96	5.96	
11		5.96	5.96	5.96	5.96	5.96	5.96	5.96	5.96	5.96	5.96	
10			5.96	5.96	5.96	5.96	5.96	5.96	5.95	5.95		
9			5.96	5.96	5.96	5.96	5.95	5.95	5.95	5.95		
8				5.96	5.96	5.96	5.95	5.95	5.95			
7				5.96	5.96	5.96	5.96	5.96	5.96			
6			5.98	5.97	5.97	5.97	5.97	5.97	5.97	5.98		
5			5.98	5.98	5.98	5.98	5.98	5.98	5.98	5.98		
4		5.99	5.99	5.99	5.98	5.98	5.98	5.99	5.99	5.99	5.99	
3		6.00	6.00	5.99	5.99	5.99	5.99	5.99	5.99	6.00	6.00	
2		6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	
1		6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	
0	6	6	6	6	6	6	6	6	6	6	6	6

BOD - DISSOLVED OXYGEN SIMULATION FOR PAGO PAGO HARBOR
Model Run No. 9 - Extreme Case Loading - Nominal Kr (0.01532/hr)
BODu = 20000 kg/day - K = 0.0152/hr - Diffusivity @6000 & 26000 m^2/hr)

Day: 50
Step in Day: 96
Time (hrs): 1200.00
Water Level (m): 0.42
Output Interval: 2400

Table of Concentrations in mg/m^3

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						29	29					
25						32	32					
24						37	37					
23						43	43					
22					53	51	51	53				
21					61	61	61	61				
20					76	76	75	73				
19					97	95	94	93				
18					123	119	118	119				
17					151	150	149	147				
16				196	192	192	192	191	198			
15				207	206	206	207	209	210			
14			227	223	222	223	225	229	231	238		
13			238	238	239	241	244	249	253	253		
12		250	250	254	257	262	268	272	275	277	287	
11		255	263	269	278	288	299	306	306	305	298	
10			279	286	300	318	343	365	359	351		
9			289	303	321	348	398	479	452	400		
8				315	329	363	450	732	575			
7				305	311	334	388	486	476			
6			252	273	277	287	308	345	346	307		
5			225	238	238	240	240	244	242	237		
4		158	184	196	199	194	189	183	178	172	149	
3		136	148	148	146	141	137	136	134	130	125	
2		102	98	93	89	86	88	93	98	98	96	
1		57	48	44	42	43	46	50	57	57	56	
0	0	0	0	0	0	0	0	0	0	0	0	0

BOD - DISSOLVED OXYGEN SIMULATION FOR PAGO PAGO HARBOR
Model Run No. 9 - Extreme Case Loading - Nominal Kr (0.01532/hr)
BODu = 20000 kg/day - K = 0.0152/hr - Diffusivity @6000 & 26000 m^2/hr)

Day: 50
Step in Day: 96
Time (hrs): 1200.00
Water Level (m): 0.42
Output Interval: 2400

Table of Dissolved Oxygen Concentrations in mg/l

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						6.10	6.10					
25						6.11	6.10					
24						6.11	6.11					
23						6.11	6.11					
22					6.10	6.10	6.10	6.10				
21					6.09	6.09	6.09	6.09				
20					6.08	6.08	6.08	6.08				
19					6.06	6.06	6.06	6.06				
18					6.04	6.04	6.04	6.04				
17					6.01	6.02	6.02	6.02				
16				5.99	5.99	5.99	5.99	5.99	5.99			
15				5.98	5.98	5.98	5.98	5.98	5.98			
14			5.97	5.98	5.98	5.98	5.98	5.98	5.98	5.97		
13			5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97		
12		5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.96	5.96	
11		5.97	5.97	5.96	5.96	5.96	5.96	5.96	5.96	5.96	5.96	
10			5.96	5.96	5.96	5.96	5.96	5.96	5.96	5.96		
9			5.96	5.96	5.96	5.96	5.96	5.95	5.95	5.95		
8				5.96	5.96	5.96	5.96	5.95	5.95			
7				5.96	5.96	5.96	5.96	5.96	5.96			
6			5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97		
5			5.98	5.98	5.98	5.98	5.98	5.98	5.98	5.98		
4		5.99	5.98	5.98	5.98	5.98	5.99	5.99	5.99	5.99	5.99	
3		5.99	5.99	5.99	5.99	5.99	5.99	6.00	6.00	6.00	6.00	
2		6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	
1		6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	
0	6	6	6	6	6	6	6	6	6	6	6	6

BOD - DISSOLVED OXYGEN SIMULATION FOR PAGO PAGO HARBOR
Model Run No. 9 - Extreme Case Loading - Nominal Kr (0.01532/hr)
BODu = 20000 kg/day - K = 0.0152/hr - Diffusivity @6000 & 26000 m^2/hr)

Day: 25
Step in Day: 96
Time (hrs): 600.00
Water Level (m): 0.55
Output Interval: 2400

Table of Concentrations in mg/m^3

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						28	28					
25						31	31					
24						36	36					
23						42	42					
22					52	49	50	52				
21					61	59	59	59				
20					77	74	73	74				
19					99	93	92	95				
18					123	118	117	121				
17					152	151	150	150				
16				198	194	194	194	195	201			
15				209	207	207	208	211	214			
14			230	225	222	223	225	230	235	245		
13			241	240	239	241	244	250	257	263		
12		255	255	256	259	264	270	276	283	291	296	
11		262	271	274	281	292	305	316	323	332	312	
10			289	294	307	326	354	387	396	401		
9			303	314	330	358	411	508	503	459		
8				323	337	371	459	744	589			
7				302	316	339	386	465	442			
6			223	261	278	291	306	325	307	261		
5			184	222	239	245	244	239	226	208		
4		108	135	167	193	197	194	185	175	159	137	
3		72	93	113	132	139	139	139	135	125	114	
2		33	45	61	75	83	88	93	95	89	77	
1		14	19	26	33	39	44	47	50	43	35	
0	0	0	0	0	0	0	0	0	0	0	0	0

BOD - DISSOLVED OXYGEN SIMULATION FOR PAGO PAGO HARBOR
Model Run No. 9 - Extreme Case Loading - Nominal Kr (0.01532/hr)
BODu = 20000 kg/day - K = 0.0152/hr - Diffusivity @6000 & 26000 m^2/hr)

Day: 25
Step in Day: 96
Time (hrs): 600.00
Water Level (m): 0.55
Output Interval: 2400

Table of Dissolved Oxygen Concentrations in mg/l

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						6.11	6.10					
25						6.11	6.11					
24						6.11	6.11					
23						6.11	6.11					
22					6.10	6.10	6.10	6.10				
21					6.09	6.09	6.09	6.09				
20					6.07	6.08	6.08	6.08				
19					6.06	6.06	6.06	6.06				
18					6.03	6.04	6.04	6.04				
17					6.01	6.02	6.02	6.02				
16				5.99	5.99	5.99	5.99	5.99	5.99			
15				5.98	5.98	5.98	5.98	5.98	5.98			
14			5.97	5.98	5.98	5.98	5.98	5.98	5.97	5.97		
13			5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97		
12		5.96	5.97	5.97	5.97	5.97	5.97	5.97	5.96	5.96	5.96	
11		5.96	5.96	5.96	5.96	5.96	5.96	5.96	5.96	5.96	5.96	
10			5.96	5.96	5.96	5.96	5.96	5.96	5.95	5.95		
9			5.96	5.96	5.96	5.96	5.95	5.95	5.95	5.95		
8				5.96	5.96	5.96	5.95	5.95	5.95			
7				5.96	5.96	5.96	5.96	5.96	5.96			
6			5.98	5.97	5.97	5.97	5.97	5.97	5.97	5.98		
5			5.98	5.98	5.98	5.98	5.98	5.98	5.98	5.98		
4		5.99	5.99	5.99	5.98	5.98	5.98	5.99	5.99	5.99	5.99	
3		6.00	6.00	5.99	5.99	5.99	5.99	5.99	5.99	6.00	6.00	
2		6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	
1		6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	
0	6	6	6	6	6	6	6	6	6	6	6	6

BOD - DISSOLVED OXYGEN SIMULATION FOR PAGO PAGO HARBOR
Model Run No. 9 - Extreme Case Loading - Nominal Kr (0.01532/hr)
BODu = 20000 kg/day - K = 0.0152/hr - Diffusivity @6000 & 26000 m^2/hr)

Day: 50
Step in Day: 96
Time (hrs): 1200.00
Water Level (m): 0.42
Output Interval: 2400

Table of Concentrations in mg/m^3

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						29	29					
25						32	32					
24						37	37					
23						43	43					
22					53	51	51	53				
21					61	61	61	61				
20					76	76	75	73				
19					97	95	94	93				
18					123	119	118	119				
17					151	150	149	147				
16				196	192	192	192	191	198			
15				207	206	206	207	209	210			
14			227	223	222	223	225	229	231	238		
13			238	238	239	241	244	249	253	253		
12		250	250	254	257	262	268	272	275	277	287	
11		255	263	269	278	288	299	306	306	305	298	
10			279	286	300	318	343	365	359	351		
9			289	303	321	348	398	479	452	400		
8				315	329	363	450	732	575			
7				305	311	334	388	486	476			
6			252	273	277	287	308	345	346	307		
5			225	238	238	240	240	244	242	237		
4		158	184	196	199	194	189	183	178	172	149	
3		136	148	148	146	141	137	136	134	130	125	
2		102	98	93	89	86	88	93	98	98	96	
1		57	48	44	42	43	46	50	57	57	56	
0	0	0	0	0	0	0	0	0	0	0	0	0

BOD - DISSOLVED OXYGEN SIMULATION FOR PAGO PAGO HARBOR
Model Run No. 9 - Extreme Case Loading - Nominal Kr (0.01532/hr)
BODu = 20000 kg/day - K = 0.0152/hr - Diffusivity @6000 & 26000 m^2/hr)

Day: 50
Step in Day: 96
Time (hrs): 1200.00
Water Level (m): 0.42
Output Interval: 2400

Table of Dissolved Oxygen Concentrations in mg/l

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						6.10	6.10					
25						6.11	6.10					
24						6.11	6.11					
23						6.11	6.11					
22					6.10	6.10	6.10	6.10				
21					6.09	6.09	6.09	6.09				
20					6.08	6.08	6.08	6.08				
19					6.06	6.06	6.06	6.06				
18					6.04	6.04	6.04	6.04				
17					6.01	6.02	6.02	6.02				
16				5.99	5.99	5.99	5.99	5.99	5.99			
15				5.98	5.98	5.98	5.98	5.98	5.98			
14			5.97	5.98	5.98	5.98	5.98	5.98	5.98	5.97		
13			5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97		
12		5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.96	5.96	
11		5.97	5.97	5.96	5.96	5.96	5.96	5.96	5.96	5.96	5.96	
10			5.96	5.96	5.96	5.96	5.96	5.96	5.96	5.96		
9			5.96	5.96	5.96	5.96	5.96	5.95	5.95	5.95		
8				5.96	5.96	5.96	5.96	5.95	5.95			
7				5.96	5.96	5.96	5.96	5.96	5.96			
6			5.97	5.97	5.97	5.97	5.97	5.97	5.97	5.97		
5			5.98	5.98	5.98	5.98	5.98	5.98	5.98	5.98		
4		5.99	5.98	5.98	5.98	5.98	5.99	5.99	5.99	5.99	5.99	
3		5.99	5.99	5.99	5.99	5.99	5.99	6.00	6.00	6.00	6.00	
2		6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	
1		6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	
0	6	6	6	6	6	6	6	6	6	6	6	6

BOD - DISSOLVED OXYGEN SIMULATION FOR PAGO PAGO HARBOR
Model Run No. 5 - Reference Case - Nominal Kr (0.00528/hr)
BODu = 0000 kg/day - K = 0.0152/hr - Diffusivity @6000 & 26000 m^2/hr)

Day: 25
Step in Day: 96
Time (hrs): 600.00
Water Level (m): 0.55
Output Interval: 2400

Table of Dissolved Oxygen Concentrations in mg/l

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						6.11	6.11					
25						6.12	6.12					
24						6.13	6.13					
23						6.14	6.14					
22					6.14	6.14	6.14	6.14				
21					6.14	6.14	6.14	6.14				
20					6.14	6.14	6.14	6.14				
19					6.14	6.14	6.14	6.14				
18					6.14	6.14	6.14	6.14				
17					6.13	6.13	6.13	6.13				
16				6.12	6.12	6.12	6.12	6.12	6.12			
15				6.12	6.12	6.12	6.12	6.12	6.12			
14			6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12		
13			6.11	6.11	6.12	6.12	6.12	6.11	6.11	6.11		
12		6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	
11		6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	
10			6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10		
9			6.10	6.10	6.10	6.10	6.10	6.09	6.09	6.10		
8				6.09	6.09	6.09	6.09	6.09	6.09			
7				6.08	6.08	6.08	6.08	6.08	6.08			
6			6.06	6.07	6.07	6.07	6.07	6.07	6.07	6.06		
5			6.05	6.06	6.07	6.07	6.06	6.06	6.06	6.06		
4		6.03	6.04	6.05	6.06	6.06	6.06	6.05	6.05	6.05	6.04	
3		6.02	6.03	6.04	6.04	6.04	6.04	6.04	6.04	6.04	6.04	
2		6.01	6.02	6.02	6.02	6.03	6.03	6.03	6.03	6.03	6.03	
1		6.01	6.01	6.01	6.01	6.01	6.02	6.02	6.02	6.01	6.01	
0	6	6	6	6	6	6	6	6	6	6	6	6

BOD - DISSOLVED OXYGEN SIMULATION FOR PAGO PAGO HARBOR
Model Run No. 5 - Reference Case - Nominal Kr (0.00528/hr)
BODu = 0000 kg/day - K = 0.0152/hr - Diffusivity @6000 & 26000 m^2/hr)

Day: 50
Step in Day: 96
Time (hrs): 1200.00
Water Level (m): 0.42
Output Interval: 2400

Table of Dissolved Oxygen Concentrations in mg/l

J/I	0	1	2	3	4	5	6	7	8	9	10	11
27												
26						6.12	6.12					
25						6.12	6.12					
24						6.13	6.13					
23						6.14	6.14					
22					6.14	6.14	6.14	6.14				
21					6.14	6.14	6.14	6.14				
20					6.14	6.14	6.14	6.14				
19					6.14	6.14	6.14	6.14				
18					6.14	6.14	6.14	6.14				
17					6.13	6.13	6.13	6.13				
16				6.12	6.12	6.12	6.12	6.12	6.12			
15				6.12	6.12	6.12	6.12	6.12	6.12			
14			6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12		
13			6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11		
12		6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	
11		6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	6.11	
10			6.11	6.10	6.10	6.10	6.10	6.10	6.10	6.10		
9			6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10		
8				6.09	6.09	6.09	6.09	6.09	6.09			
7				6.08	6.08	6.08	6.08	6.08	6.08			
6			6.07	6.08	6.07	6.07	6.07	6.07	6.07	6.07		
5			6.06	6.07	6.07	6.07	6.06	6.06	6.06	6.06		
4		6.05	6.06	6.06	6.06	6.06	6.05	6.05	6.05	6.05	6.05	
3		6.04	6.05	6.05	6.04	6.04	6.04	6.04	6.04	6.04	6.04	
2		6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	
1		6.02	6.02	6.02	6.02	6.02	6.02	6.02	6.02	6.02	6.02	
0	6	6	6	6	6	6	6	6	6	6	6	6

APPENDIX VIII
WATER QUALITY MONITORING DATA

Water Quality Data

The water quality data used for the model verification study report (No. 1) is provided below in the following format and order:

- Summary of TN data with values > 0.2 mg/l highlighted
- Plot of TN with distance along the Harbor axis
- Plot of TN with time for inner harbor stations
- Plot of TN with time for middle harbor stations
- Plot of TN with time for mixing zone area
- Plot of TN with time for outer harbor

- Summary of TP data with values > 0.03 mg/l highlighted
- Plot of TP with distance along the Harbor axis
- Plot of TP with time for inner harbor stations
- Plot of TP with time for middle harbor stations
- Plot of TP with time for mixing zone area
- Plot of TP with time for outer harbor

- Summary of Chlorophyll-a data with values > 1.0 highlighted

- Summary of Secchi depth data

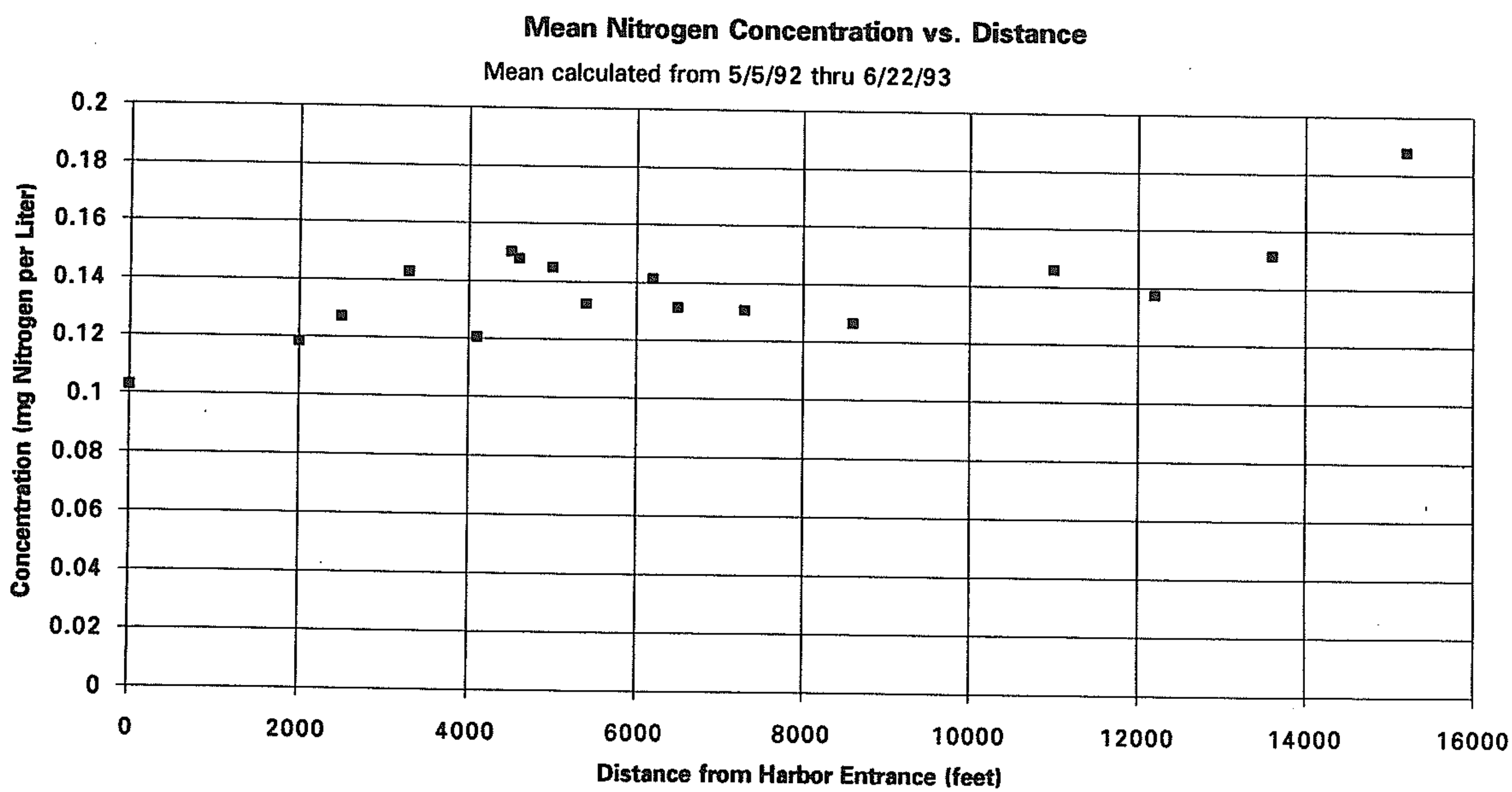
- Summary of Turbidity data

- Location of ASG Sampling Stations (historic)
- Location of ASG Sampling Stations (mixing zone)
- Table of stations distances along centerline of harbor and model cell locations of stations

Total Nitrogen (mg N/l)											
Harbor Station	Sampling Date										Average
	2/27/92	3/19/92	5/5/92	5/28/92	8/6/92	10/6/92	Dec 92?	1/22/93	3/9/93	6/22/93	
5-3	0.137	0.186	0.104	0.139	0.166	0.149	NS	0.066	0.080	0.082	0.123
5-60	0.119	0.161	0.095	0.184	0.120	0.073	NS	0.099	0.069	0.014	0.104
6-3	0.187	0.132	0.122	**0.272**	0.132	0.078	0.138	0.124	0.041	0.122	0.135
6-60	0.167	0.134	0.115	0.111	0.130	0.151	0.103	0.094	0.035	0.122	0.116
7-3	0.159	0.142	0.152	0.119	0.132	0.122	0.176	0.087	0.071	0.061	0.122
7-60	0.156	0.128	0.124	0.136	0.094	0.186	0.154	0.058	**0.237**	0.122	0.140
8-3	0.181	0.146	0.116	0.172	0.123	0.091	0.133	0.106	0.052	0.126	0.125
8-60	0.146	0.186	0.124	**0.202**	0.183	0.067	0.120	0.094	0.024	0.193	0.134
8A-3	0.178	0.149	0.087	0.142	0.175	0.137	0.150	0.133	0.035	0.109	0.130
8A-60	0.148	0.197	0.120	**0.286**	0.169	0.156	0.141	0.155	0.164	0.160	0.170
9-3	0.193	0.162	0.079	0.120	**0.212**	0.158	0.166	0.131	0.091	0.109	0.142
9-60	0.190	0.153	0.093	0.122	0.148	0.105	0.151	0.133	0.088	0.196	0.138
9A-3	0.145	0.141	0.109	0.155	0.183	0.121	**0.278**	0.070	0.136	0.195	0.153
9A-60	0.134	0.156	0.115	0.106	0.108	0.110	0.108	0.089	0.080	0.059	0.107
10-3	0.195	0.115	0.146	0.122	0.160	0.117	0.138	0.089	0.088	**0.255**	0.143
10-60	0.128	0.119	0.124	0.112	0.134	0.113	0.097	0.102	0.028	**0.293**	0.125
11-3	**0.209**	0.154	0.168	0.143	0.197	0.116	0.127	0.086	0.101	0.193	0.149
11-60	**0.225**	0.126	0.149	0.114	0.116	**0.357**	0.109	0.110	0.088	0.160	0.155
11A-3	**0.212**	0.128	0.084	0.147	**0.222**	0.103	0.156	0.108	0.041	0.193	0.139
11A-60	**0.209**	0.168	0.104	**0.294**	0.154	0.120	0.148	0.076	0.088	0.160	0.152
12-3	**0.237**	0.127	0.097	0.103	**0.221**	0.172	0.188	0.170	0.071	**0.252**	0.164
12-60	0.181	0.150	0.112	0.061	**0.237**	0.179	0.183	0.131	0.052	0.193	0.148
13-3	**0.274**	0.192	0.157	0.148	**0.389**	**0.229**	**0.411**	0.144	0.102	0.141	**0.219**
13-30	0.200	0.166	0.182	**0.208**	0.147	0.144	0.193	0.176	0.039	0.195	0.165
14-3	NS	NS	0.133	0.147	0.183	0.106	0.143	0.086	0.064	0.155	0.127
14-60	NS	NS	0.138	**0.228**	**0.550**	0.134	0.151	0.086	0.052	0.010	0.169
15-3	NS	NS	0.180	0.143	0.200	0.150	0.134	0.095	0.115	0.185	0.150
15-60	NS	NS	0.139	**0.233**	0.178	0.129	0.111	0.111	0.115	0.045	0.133
16-3	NS	NS	0.103	0.164	**0.337**	0.183	0.114	0.130	0.039	0.036	0.138
16-60	NS	NS	0.166	0.115	0.150	0.137	0.103	0.097	0.147	0.095	0.126
17-3	NS	NS	0.122	**0.254**	**0.239**	0.144	0.112	0.086	0.115	0.140	0.152
17-60	NS	NS	0.115	**0.261**	**0.244**	0.164	0.110	0.097	0.090	0.111	0.149
18-3	NS	NS	0.133	0.156	**0.216**	0.116	0.117	0.128	0.090	0.185	0.143
18-60	NS	NS	0.130	0.183	**0.256**	0.134	0.108	0.090	0.090	0.156	0.143

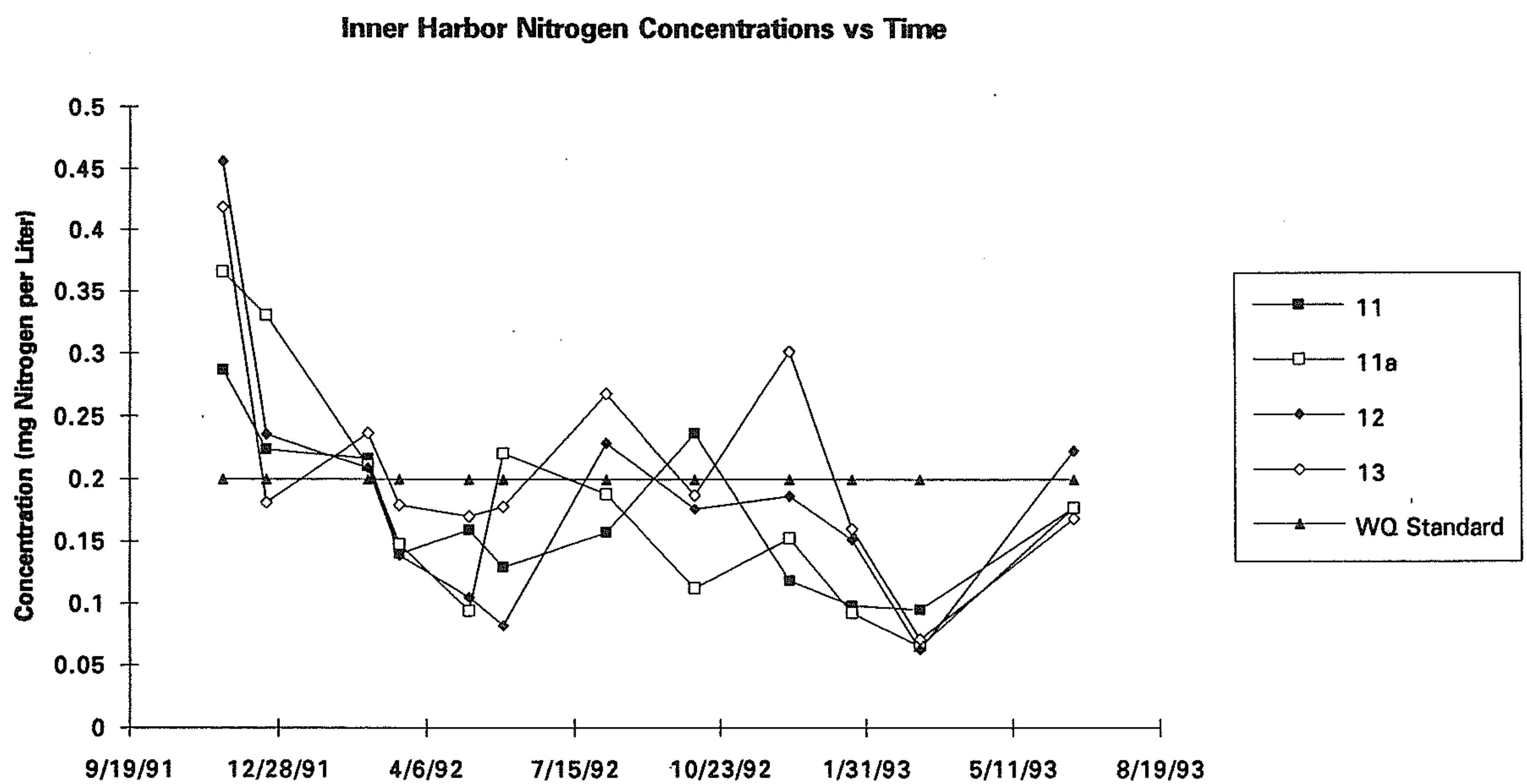
Notes:

NS = not sampled


Mean Nitrogen Concentration vs. Distance
Mean calculated from 5/5/92 thru 6/22/93
Concentration (mg Nitrogen per Liter)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
2000
4000
6000
8000
10000
12000
14000
16000
Distance from Harbor Entrance (feet)

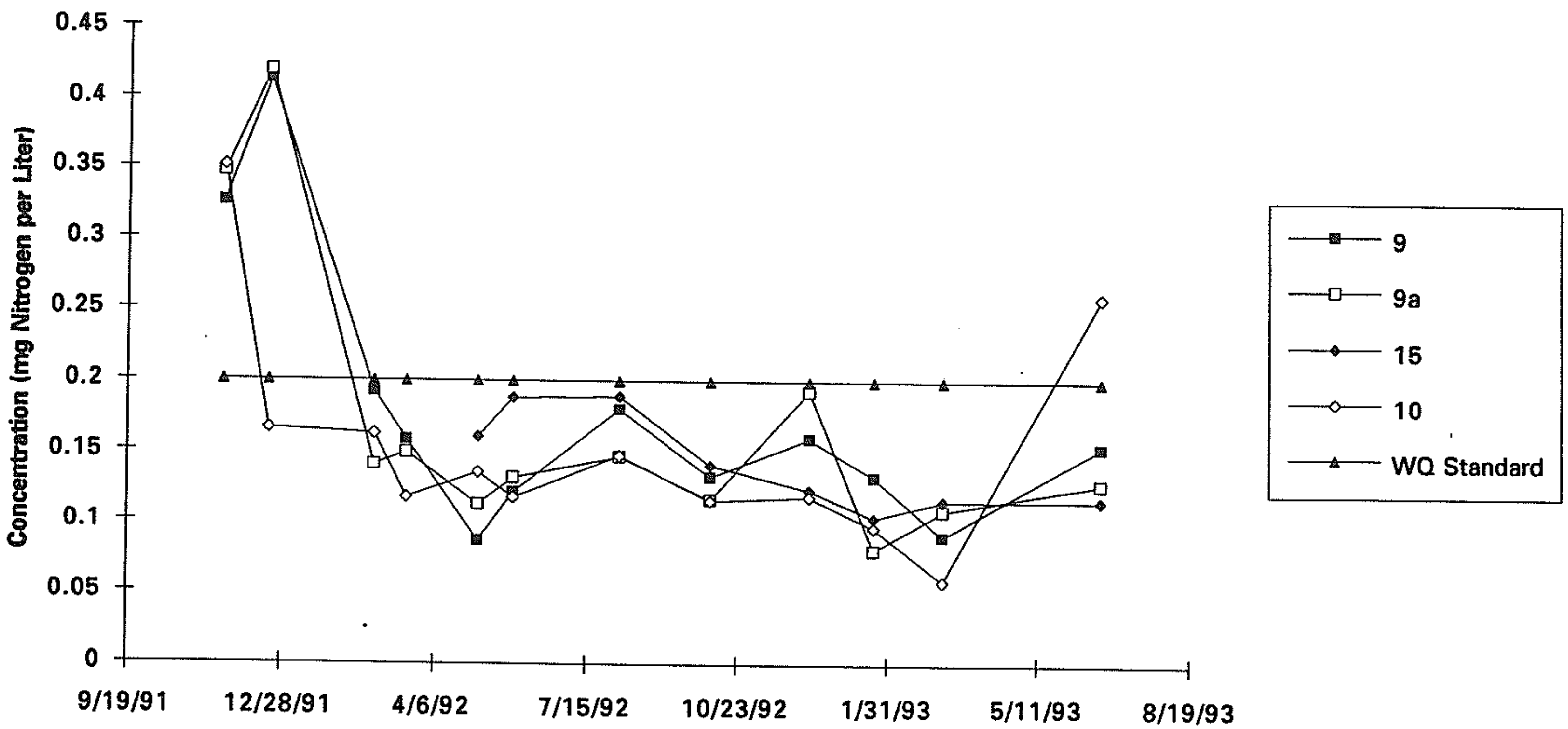
VIII-3

VIII · 4

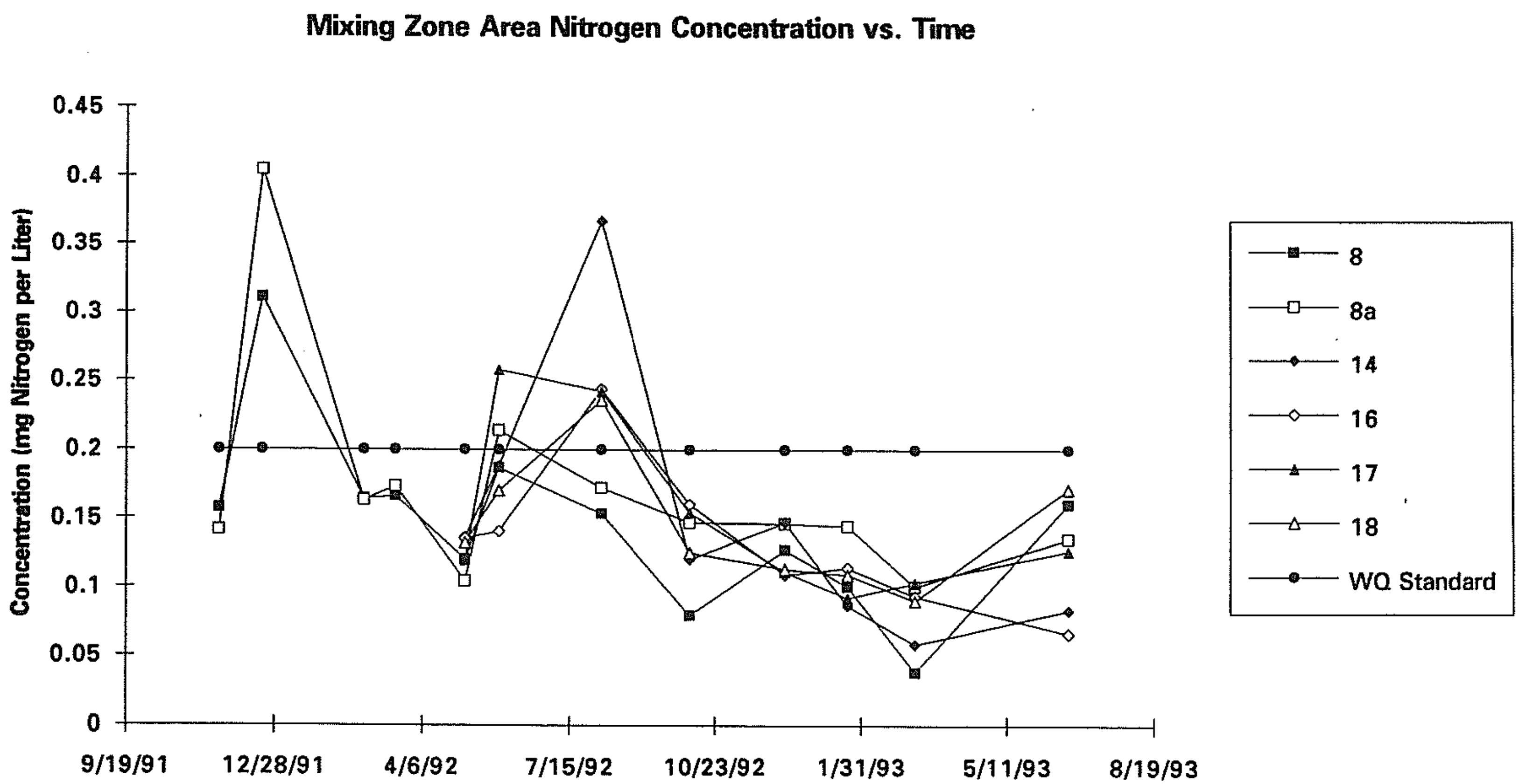

Inner Harbor Nitrogen Concentrations vs Time
Concentration (mg Nitrogen per Liter)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
9/19/91
12/28/91
4/6/92
7/15/92
10/23/92
1/31/93
5/11/93
8/19/93
11
11a
12
13
WQ Standard

VIII 5

Middle Harbor Nitrogen Concentration vs. Time

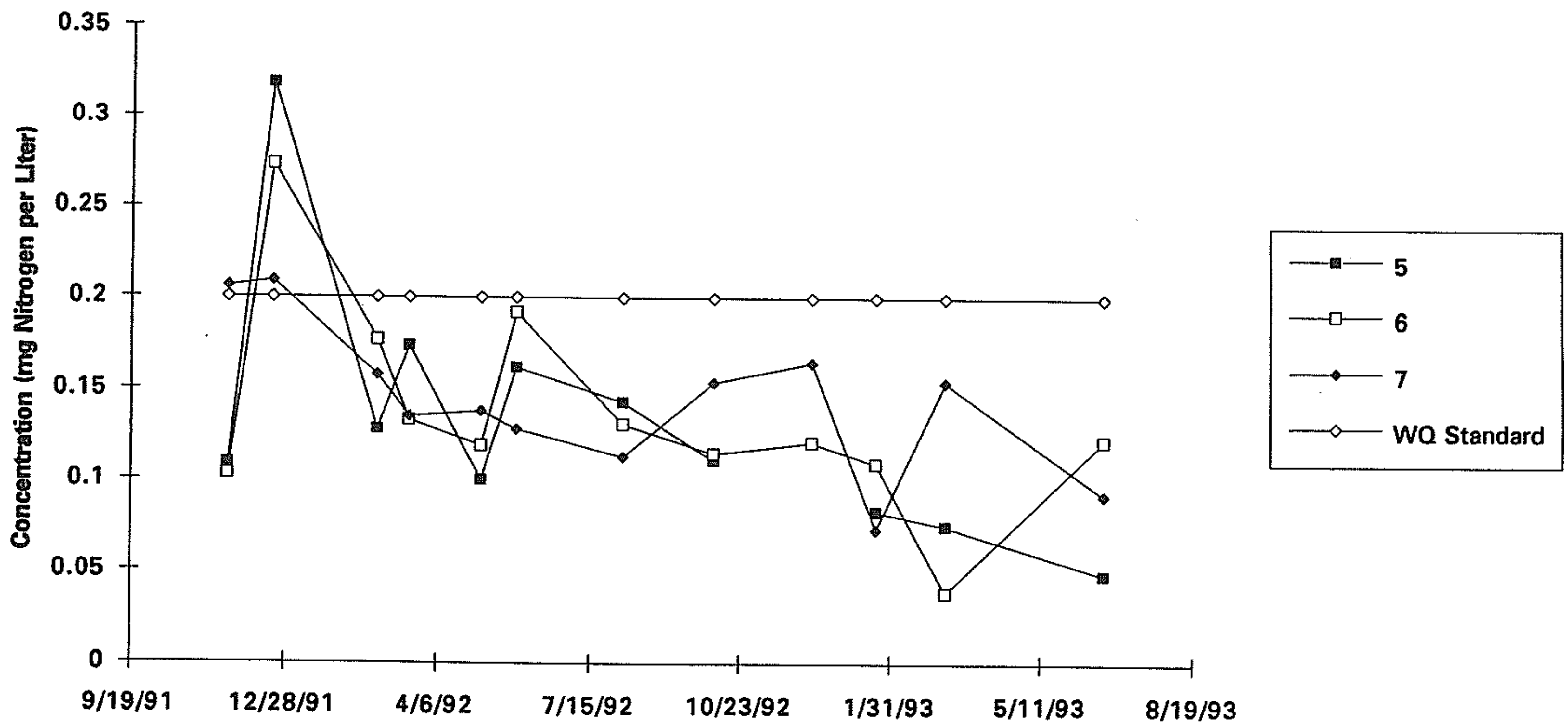


VIII 6


Mixing Zone Area Nitrogen Concentration vs. Time
Concentration (mg Nitrogen per Liter)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
9/19/91
12/28/91
4/6/92
7/15/92
10/23/92
1/31/93
5/11/93
8/19/93
8
8a
14
16
17
18
WQ Standard

VIII 7

Outer Harbor Nitrogen Concentration vs. Time



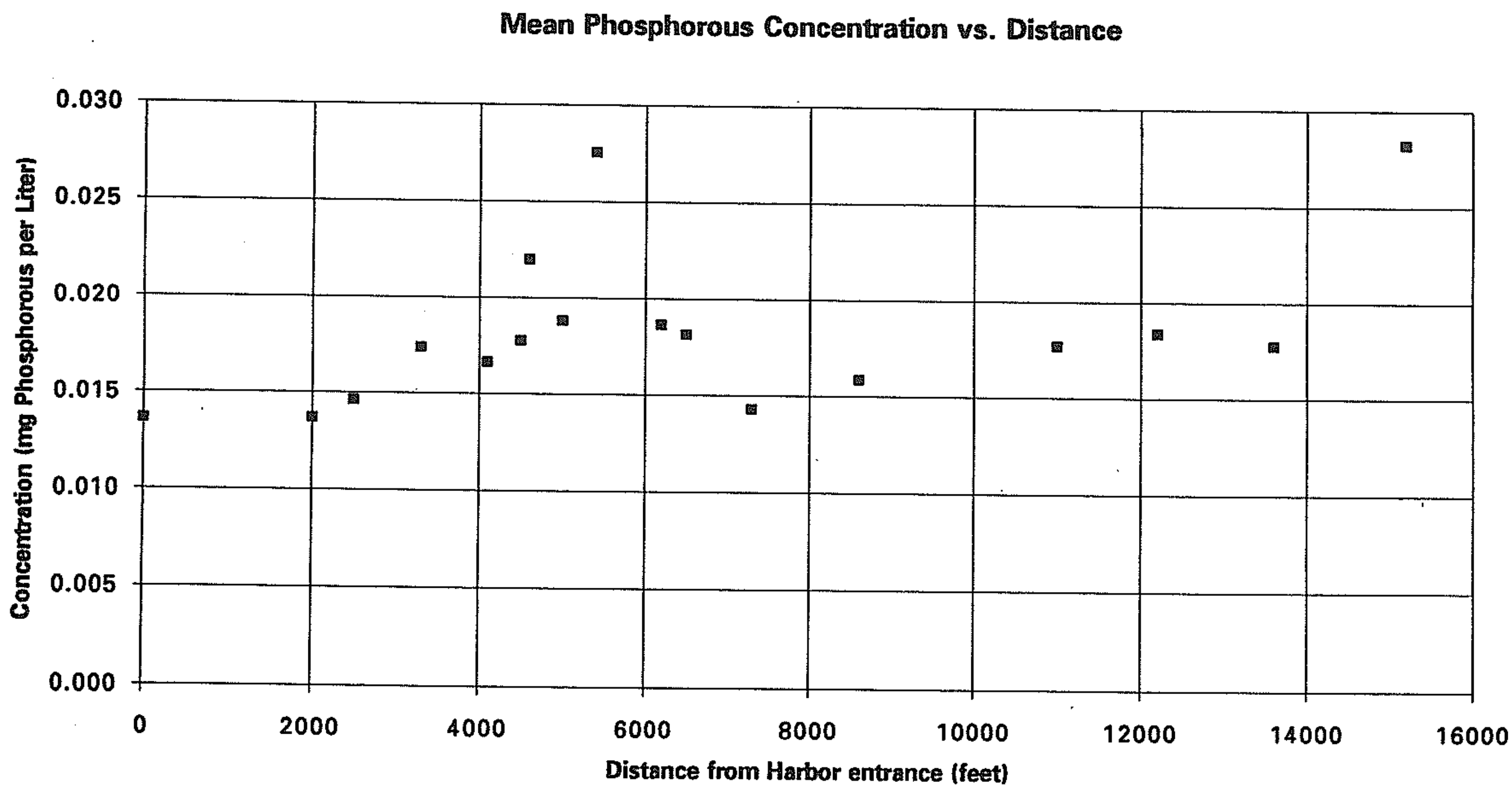
Total Phosphorus (mg P/l)											
Harbor	Sampling Date										
Station	2/27/92	3/19/92	5/5/92	5/28/92	8/6/92	10/6/92	Dec 92?	1/22/93	3/9/93	6/22/93	Average
5-3	0.012	**0.033**	0.027	0.017	0.013	0.011	NS	0.012	0.011	0.009	0.016
5-60	0.023	0.026	0.023	0.014	0.004	0.001	NS	0.018	0.008	0.023	0.016
6-3	0.019	0.019	0.025	0.019	0.008	0.001	0.018	0.019	0.007	0.008	0.014
6-60	0.021	0.027	0.028	0.010	0.002	0.002	0.018	**0.031**	0.017	0.006	0.016
7-3	**0.033**	0.025	0.027	0.012	0.008	0.012	**0.036**	0.015	0.012	0.006	0.019
7-60	0.017	0.018	0.026	0.016	0.003	0.016	0.018	0.011	0.006	0.010	0.014
8-3	0.029	0.025	0.021	0.024	0.014	0.008	0.016	0.019	0.016	0.013	0.019
8-60	0.018	**0.036**	0.022	0.027	0.022	0.012	0.014	0.016	0.013	0.009	0.019
8A-3	**0.033**	0.017	0.022	**0.033**	0.023	0.010	0.020	0.023	0.011	0.013	0.021
8A-60	**0.035**	0.021	0.019	**0.034**	0.020	0.009	0.019	0.024	0.006	0.015	0.020
9-3	**0.039**	0.018	0.029	0.021	0.022	0.009	0.022	0.020	0.016	0.013	0.021
9-60	**0.050**	0.016	**0.033**	0.023	0.011	0.012	0.002	0.019	0.006	0.014	0.019
9A-3	**0.050**	0.013	0.025	0.020	0.016	0.010	**0.034**	0.010	0.009	0.012	0.020
9A-60	**0.078**	0.016	**0.033**	0.020	0.011	0.010	0.010	0.013	0.015	0.006	0.021
10-3	**0.051**	0.016	**0.032**	0.021	0.012	0.009	0.020	0.012	0.007	0.009	0.019
10-60	**0.064**	0.016	0.024	0.018	0.006	0.009	0.010	0.014	0.018	0.008	0.019
11-3	**0.035**	0.023	0.029	0.024	0.018	0.007	0.020	0.010	0.010	0.008	0.018
11-60	**0.038**	0.016	**0.032**	0.021	0.005	**0.041**	0.016	0.014	0.019	0.009	0.021
11A-3	**0.047**	0.026	0.021	0.024	0.016	0.008	0.026	0.014	0.023	0.010	0.022
11A-60	**0.031**	**0.034**	0.017	**0.068**	0.010	0.009	0.025	0.012	0.005	0.006	0.022
12-3	**0.037**	0.023	0.030	0.029	0.014	0.012	**0.030**	0.022	0.007	0.010	0.021
12-60	**0.032**	0.018	0.022	0.019	0.012	0.012	0.026	0.016	0.006	0.017	0.018
13-3	**0.042**	**0.033**	**0.031**	**0.044**	0.020	**0.043**	**0.088**	0.024	0.011	0.009	**0.035**
13-30	0.027	0.029	0.028	**0.052**	0.010	0.017	0.027	0.028	0.014	0.006	0.024
14-3	NS	NS	**0.032**	0.001	0.011	0.001	0.014	0.017	0.011	0.017	0.013
14-60	NS	NS	**0.033**	**0.034**	**0.082**	**21.1***	0.016	0.012	0.016	0.012	0.029 **
15-3	NS	NS	0.026	0.025	0.018	0.017	0.014	0.016	0.013	0.006	0.017
15-60	NS	NS	**0.035**	**0.040**	0.015	0.019	0.014	0.019	0.011	0.010	0.020
16-3	NS	NS	0.028	0.027	0.017	0.017	0.020	0.022	0.007	0.013	0.019
16-60	NS	NS	0.023	0.019	**0.190**	0.018	0.010	0.014	0.014	0.002	0.014 **
17-3	NS	NS	0.021	**0.034**	0.021	0.019	0.016	0.014	0.006	0.017	0.019
17-60	NS	NS	0.025	**0.038**	0.011	0.019	0.014	0.014	0.006	0.009	0.017
18-3	NS	NS	0.014	0.026	0.024	0.016	0.010	0.020	0.006	0.009	0.016
18-60	NS	NS	0.029	0.026	**0.036**	0.018	0.012	0.017	0.004	0.011	0.019

Notes:

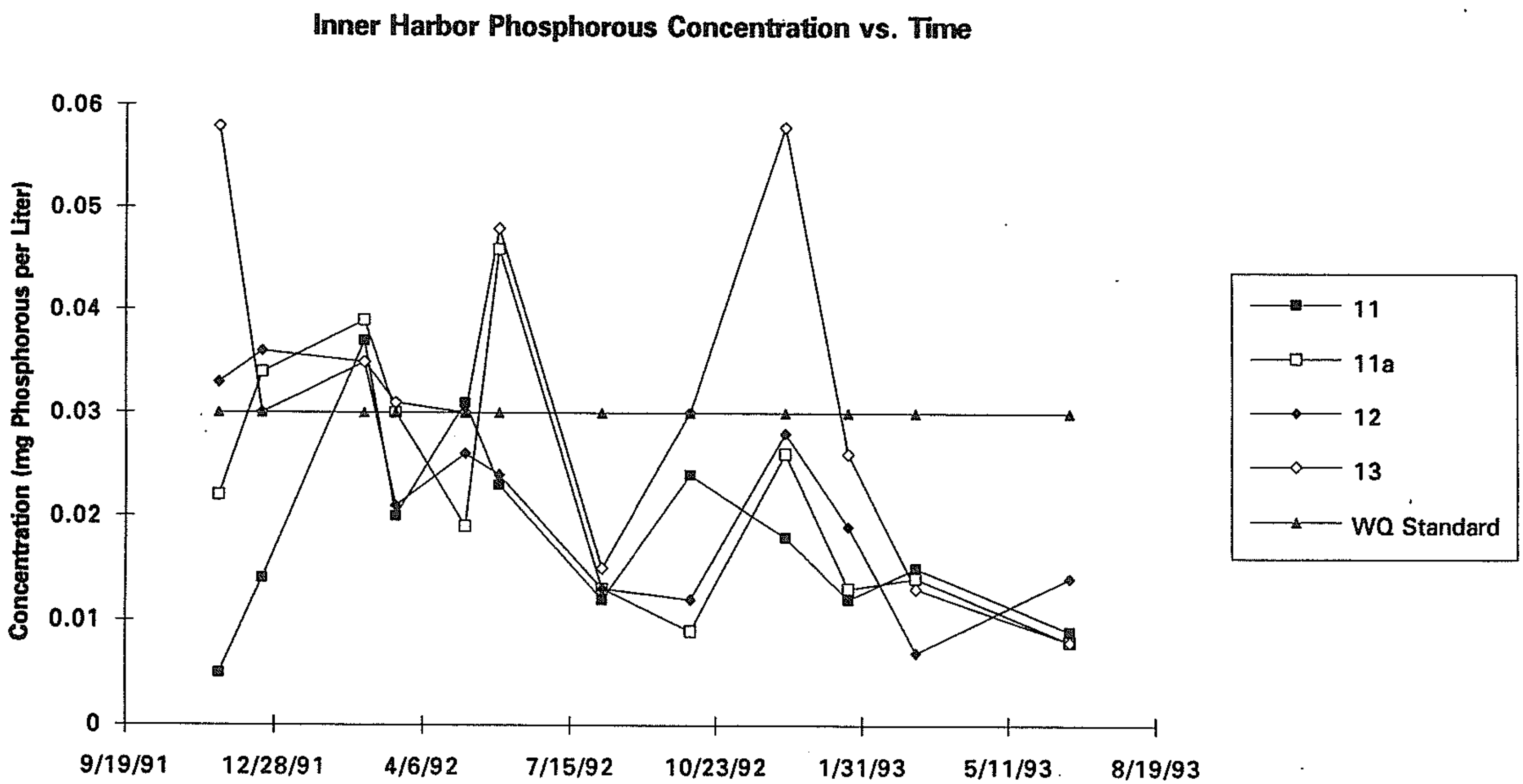
* Value verified by repeat analysis.

** Average does not include extreme values.

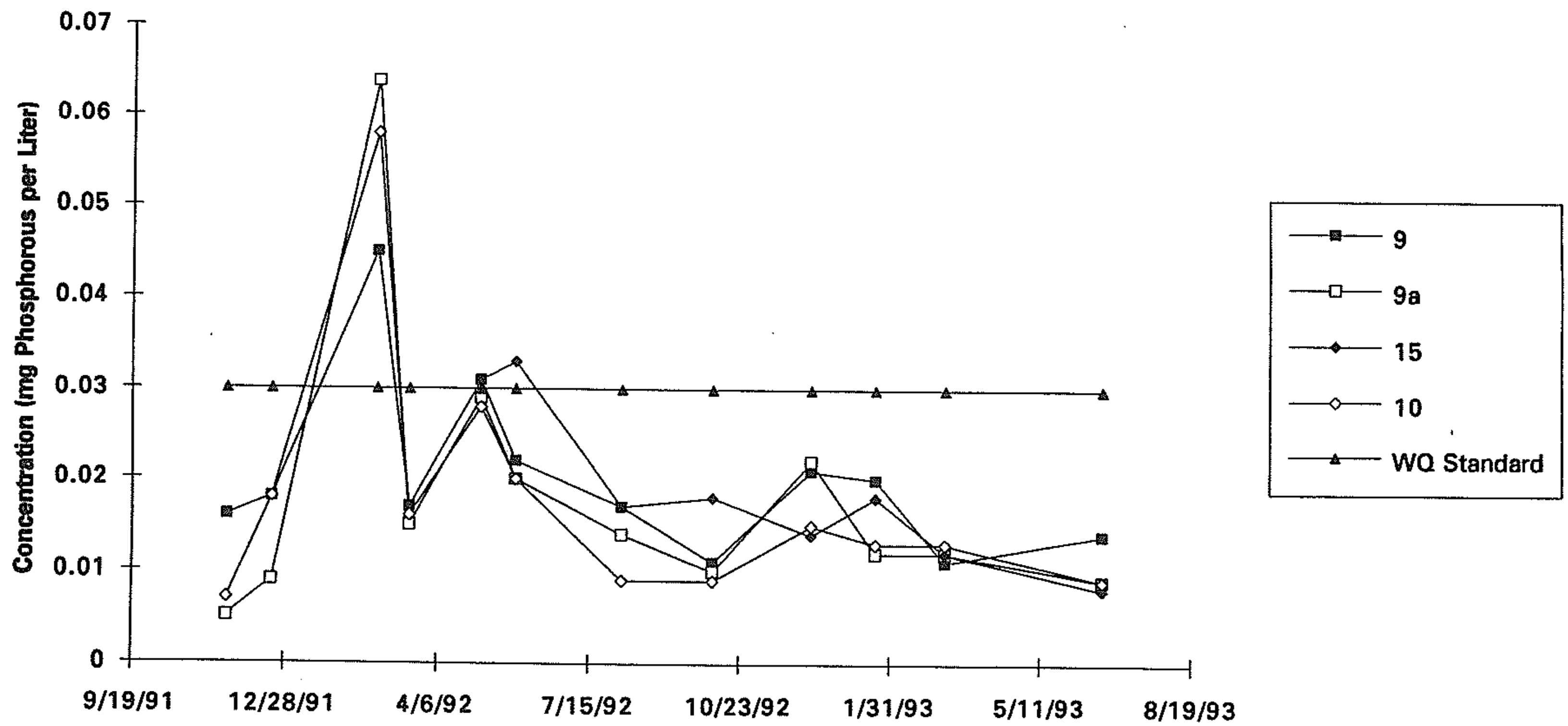
NS = not sampled


Mean Phosphorous Concentration vs. Distance
Concentration (mg Phosphorous per Liter)
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0
2000
4000
6000
8000
10000
12000
14000
16000
Distance from Harbor entrance (feet)

VIII 9

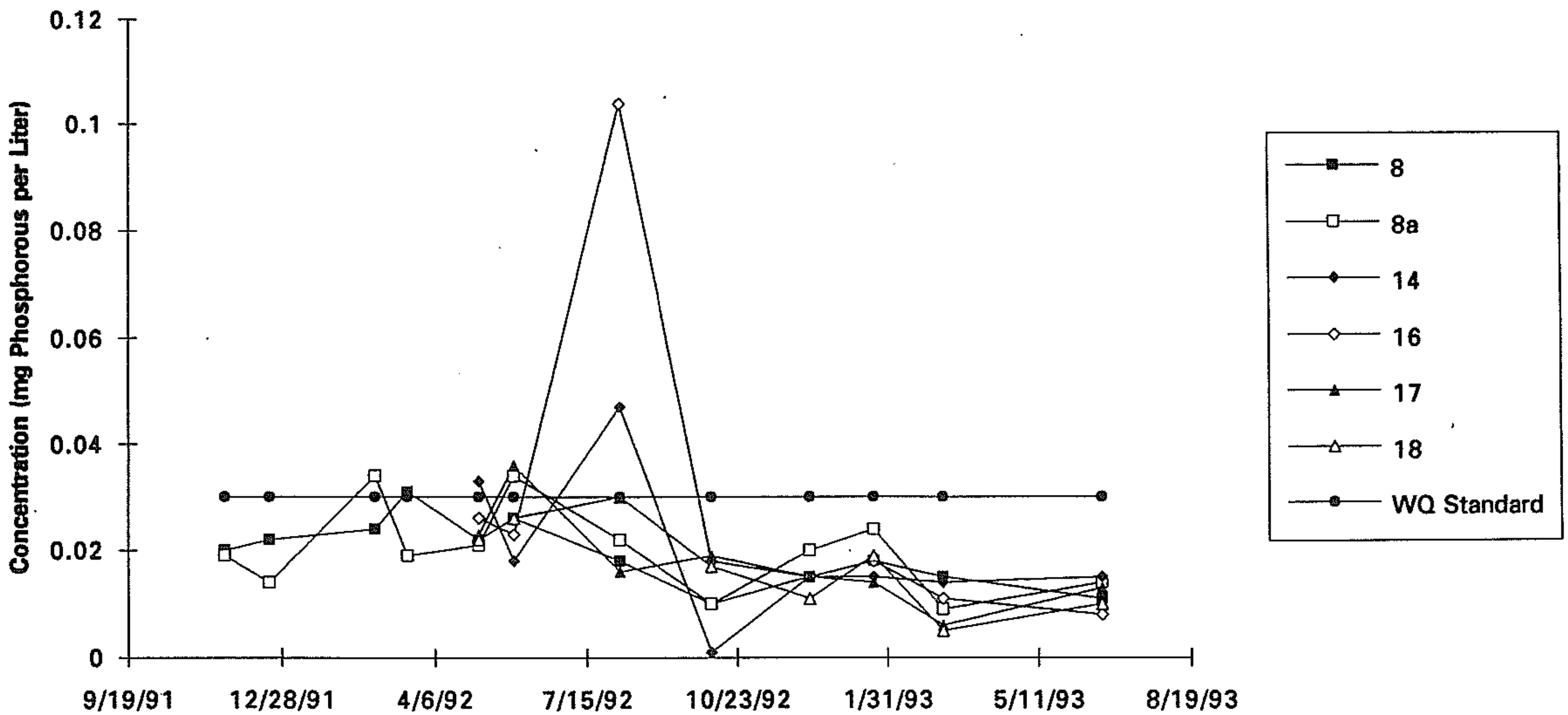

Inner Harbor Phosphorous Concentration vs. Time
Concentration (mg Phosphorous per Liter)
0.06
0.05
0.04
0.03
0.02
0.01
0
9/19/91
12/28/91
4/6/92
7/15/92
10/23/92
1/31/93
5/11/93
8/19/93
11
11a
12
13
WQ Standard

Middle Harbor Phosphorous Concentration vs. Time

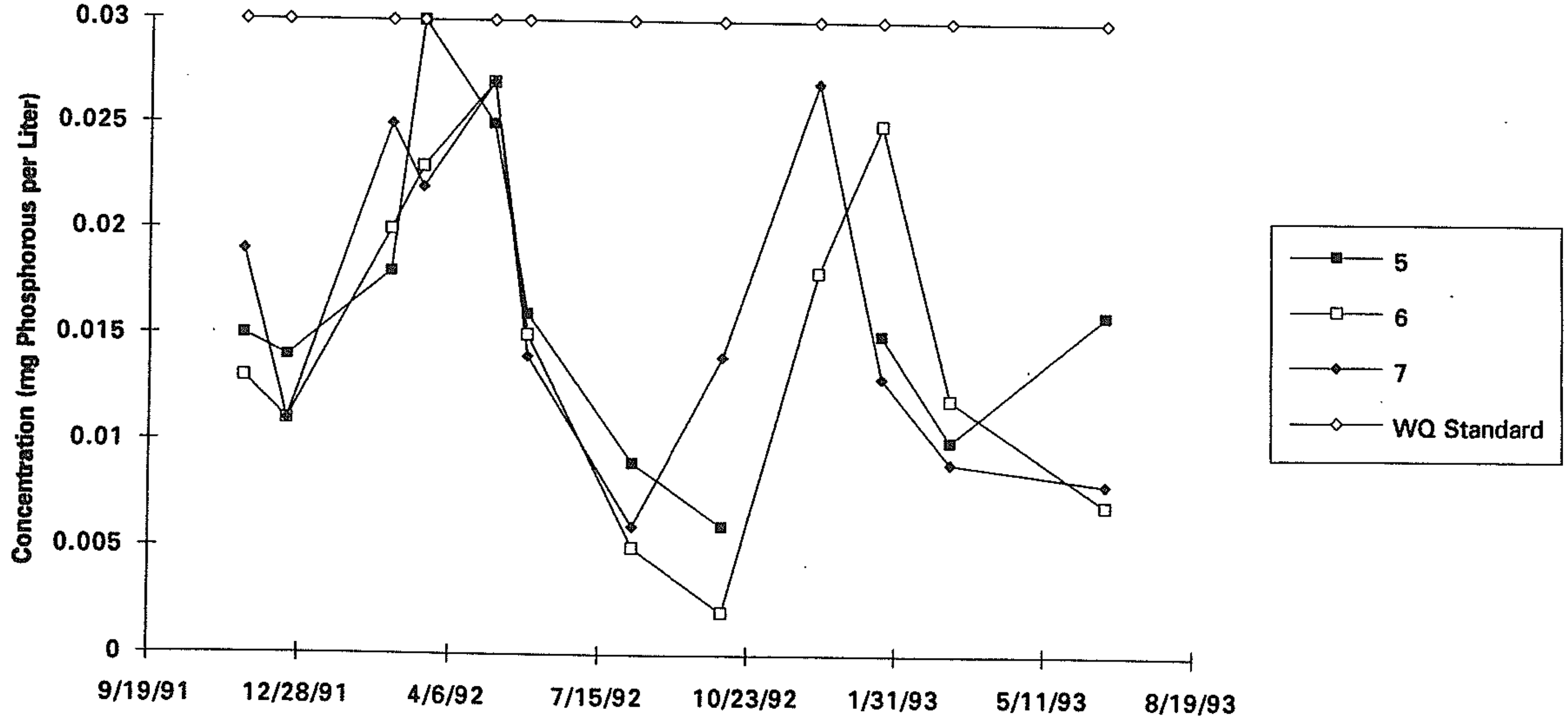


21 - IIIA

Mixing Zone Area Phosphorous Concentration vs. Time



Outer Harbor Phosphorous Concentration vs. Time



VIII-13

Chlorophyll a (mg/m3)											
Harbor Station	Sampling Date										Average
	2/27/92	3/19/92	5/5/92	5/28/92	8/6/92	10/6/92	Dec 92?	1/22/93	3/9/93	6/22/93	
5-3	0.21	0.74	NS	NS	**1.38**	0.19	NS	**1.25**	0.59	0.33	0.67
5-60	0.15	0.08	NS	NS	0.49	0.16	NS	**1.19**	0.31	0.33	0.39
6-3	0.76	0.75	NS	NS	0.74	0.28	0.96	0.21	0.36	0.22	0.54
6-60	0.98	0.47	NS	NS	0.58	0.28	0.57	0.18	0.24	0.20	0.44
7-3	0.61	0.19	NS	NS	0.23	0.38	**1.89**	0.95	0.80	0.43	0.69
7-60	0.32	0.26	NS	NS	0.18	0.25	0.75	0.54	0.48	0.42	0.40
8-3	**1.30**	**1.01**	NS	NS	0.65	0.52	**2.66**	0.45	0.85	0.68	**1.02**
8-60	**1.11**	0.66	NS	NS	0.62	0.37	**2.61**	0.71	0.34	0.64	0.88
8A-3	**1.33**	0.89	NS	NS	**2.66**	0.45	**2.09**	0.82	0.95	0.65	**1.23**
8A-60	**1.13**	0.56	NS	NS	**1.20**	0.33	**1.93**	0.74	0.65	0.66	0.90
9-3	**1.37**	0.96	NS	NS	0.64	0.26	**1.23**	0.17	0.80	**1.49**	0.87
9-60	**1.18**	0.44	NS	NS	**1.33**	0.27	**1.44**	0.18	0.51	**1.46**	0.85
9A-3	0.55	0.83	NS	NS	**1.41**	0.18	**1.44**	0.44	0.67	*	0.79
9A-60	0.66	0.61	NS	NS	0.93	0.30	**1.63**	0.42	0.67	**	0.75
10-3	0.68	0.50	NS	NS	**1.68**	0.36	**2.44**	0.80	0.56	**2.35**	**1.17**
10-60	0.96	0.41	NS	NS	0.47	0.31	**1.56**	**1.03**	0.52	**1.22**	0.81
11-3	**1.41**	**1.59**	NS	NS	0.26	0.61	**1.88**	0.47	0.56	**1.03**	0.98
11-60	**1.09**	0.87	NS	NS	0.53	0.49	**1.54**	0.45	0.50	**1.05**	0.82
11A-3	**1.34**	**1.29**	NS	NS	0.48	0.51	**1.32**	**1.28**	0.82	**1.36**	**1.05**
11A-60	**1.32**	**1.35**	NS	NS	**1.90**	0.71	**1.95**	**1.01**	0.56	**1.81**	**1.33**
12-3	**1.46**	0.98	NS	NS	0.38	0.81	**4.70**	**1.28**	0.86	**1.48**	**1.49**
12-60	**2.15**	0.84	NS	NS	0.29	0.70	**3.15**	0.98	**1.85**	**1.52**	**1.44**
13-3	**1.63**	**4.79**	NS	NS	0.94	0.85	**7.66**	NS	**2.22**	**1.53**	**2.80**
13-30	**1.77**	**2.56**	NS	NS	0.90	0.65	**2.74**	0.93	**1.66**	**2.02**	**1.65**
14-3	NS	NS	NS	NS	**1.50**	0.52	**1.49**	0.43	0.66	0.71	0.89
14-60	NS	NS	NS	NS	0.21	0.78	**2.05**	**1.16**	0.57	0.66	0.91
15-3	NS	NS	NS	NS	0.83	0.67	**1.56**	0.35	0.61	**1.12**	0.86
15-60	NS	NS	NS	NS	0.47	0.42	**1.85**	0.33	0.56	**1.02**	0.78
16-3	NS	NS	NS	NS	**1.00**	0.47	**2.78**	0.62	0.67	0.69	**1.04**
16-60	NS	NS	NS	NS	0.71	0.47	**2.00**	0.45	0.56	0.61	0.80
17-3	NS	NS	NS	NS	**1.78**	0.44	**2.36**	0.38	0.93	0.60	**1.08**
17-60	NS	NS	NS	NS	**1.11**	0.64	**1.79**	**1.08**	0.67	0.43	0.95
18-3	NS	NS	NS	NS	**6.58**	0.28	**1.40**	**1.02**	0.84	0.61	**1.79**
18-60	NS	NS	NS	NS	**4.47**	0.46	**1.98**	**1.24**	0.35	0.56	**1.51**

Notes:

* 68.0 x (10/vol filtered) x 1.450 x 5 = 9A-3

** 46.5 x (10/ vol. filtered) x 1.450 x 5 = value for 9A-60

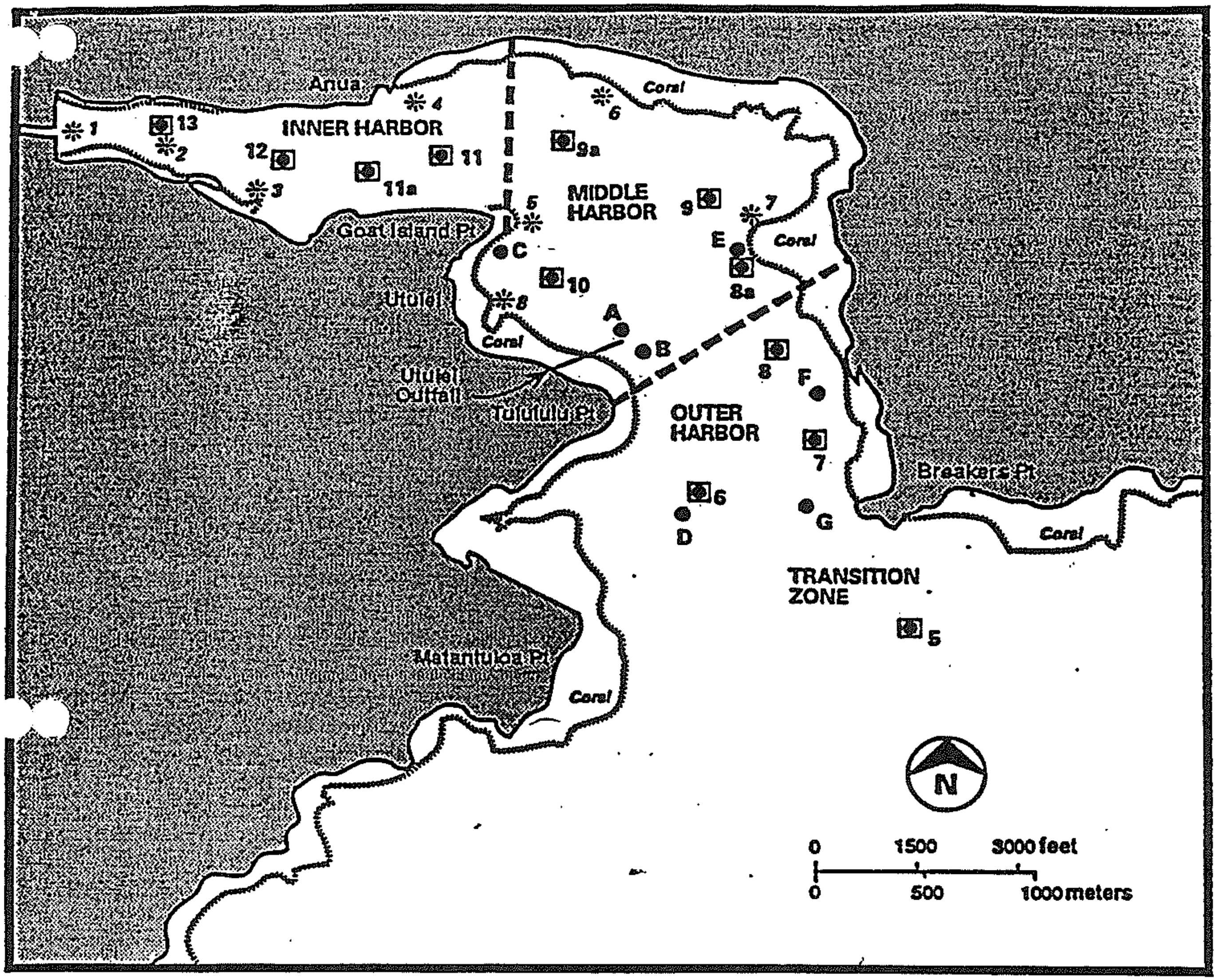
NS = not sampled

Observed Secchi Depths[1]			
Station[2]	Secchi Depth (feet)		
	6 May 1992	6 Oct 1992	22 June 1993
5	>65	35	43
6	>65	38	40
7	>65	34	26
8	>65	34	32
8A	>65	65	30
9	>65	65	30
9A	>65	47	29
10	>65	31	28
11	60	42	27
11A	19	32	29
12	21	29	22
13	15	22	20
14	>65	45	29
15	>65	65	29
16	>65	48	32
17	>65	40	28
18	>65	30	25

[1]Data supplied by ASEPA.
[2]Station locations shown on on following figures.

Observed Turbidity[1]						
Station[2]	Turbidity (NTU)					
	6 May 1992		6 Oct 1992		22 June 1993	
Depth (ft)→	3	60	3	60	3	60
5	0.4	0.4	0.5	0.4	0.3	0.4
6	0.4	0.4	0.4	0.3	0.2	0.4
7	0.4	0.4	0.4	0.4	0.2	0.3
8	0.4	0.4	0.4	0.4	0.3	0.5
8A	0.4	0.4	0.5	0.4	0.4	0.5
9	0.6	0.5	0.5	0.4	0.5	0.4
9A	0.5	0.5	0.5	0.4	0.3	0.4
10	0.5	0.5	0.7	0.5	0.4	0.5
11	0.6	0.6	0.5	0.4	0.4	0.3
11A	0.9	1.0	0.5	0.5	0.5	0.5
12	0.5	0.6	0.5	0.7	0.4	0.5
13	1.0	1.0	3.5	1.4	0.6	0.7
14	0.6	0.5	0.5	0.5	0.4	0.5
15	0.5	0.7	0.7	0.5	0.4	0.5
16	0.5	0.9	0.5	0.4	0.5	0.3
17	0.6	0.6	0.5	0.5	0.3	0.4
18	0.5	0.7	0.4	0.4	0.2	0.3

[1]Data supplied by ASEPA.
[2]Station locations shown on following figures.



LEGEND

- ASG Sampling Station
- Utulei WWTP Station
- CH2M HILL Field Measurement Station (1/19/91)

FIGURE 2. LOCATION OF WATER QUALITY STATIONS IN PAGO PAGO HARBOR

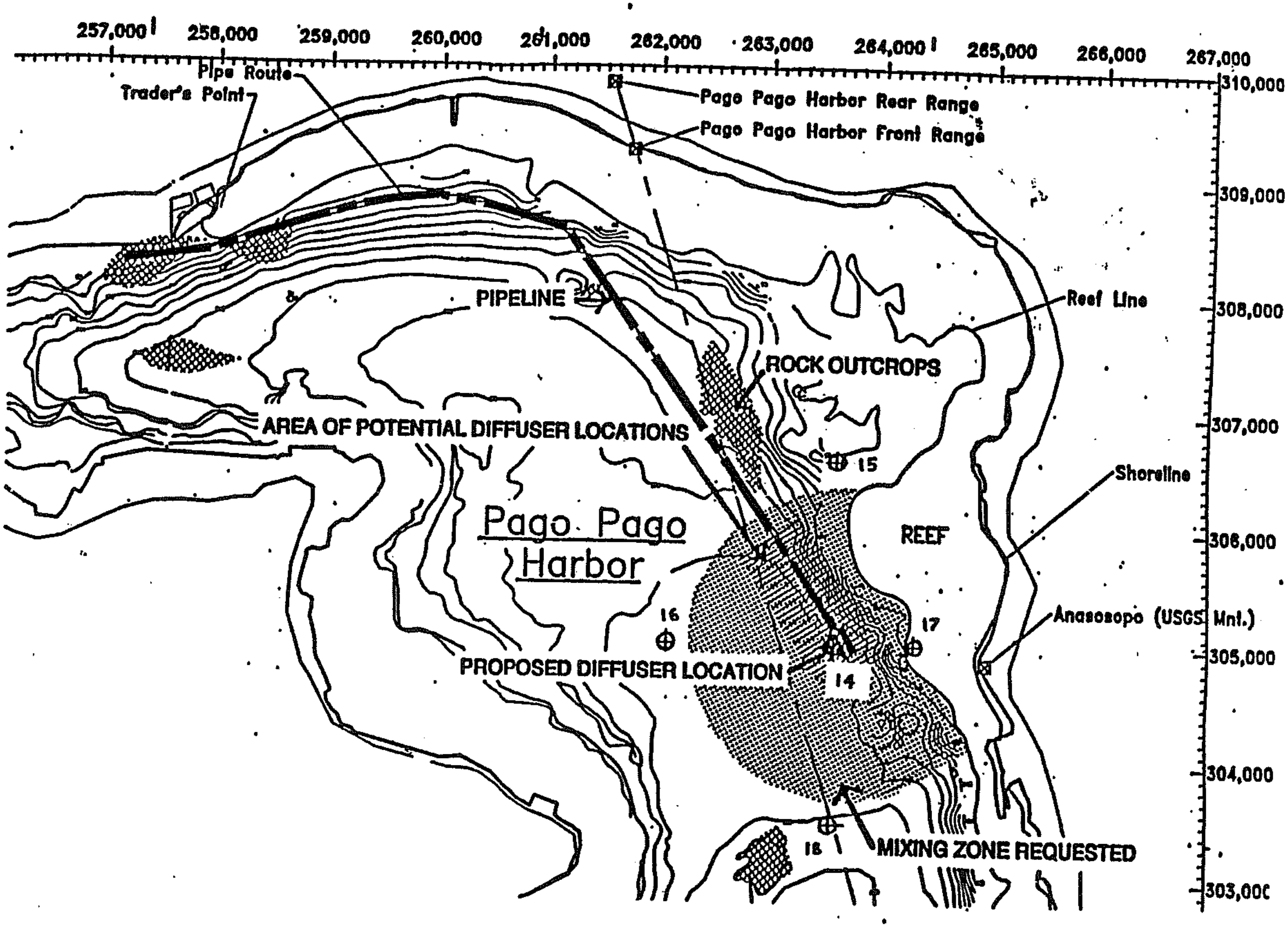


FIGURE 1. NEW MONITORING STATIONS IN PAGO PAGO HARBOR (14-18)

Station Distances Along Harbor Centerline			
Station	Distance from Harbor Entrance[1] (feet)	Corresponding Model Cell[1]	
		I	J
5	0		
6	2000	6	3
7	2500	9	4
18	3300		
8	4100	8	6
17	4500		
14	4600		
8A	5000	7	8
16	5400	7	8
15	6200		
9	6500	7	10
10	7300	3	11
9A	8600	7	13
11	11000	5	17
11A	12200	5	19
12	13600	5	21
13	15200	5	32

[1] Distances and cell locations are approximate.